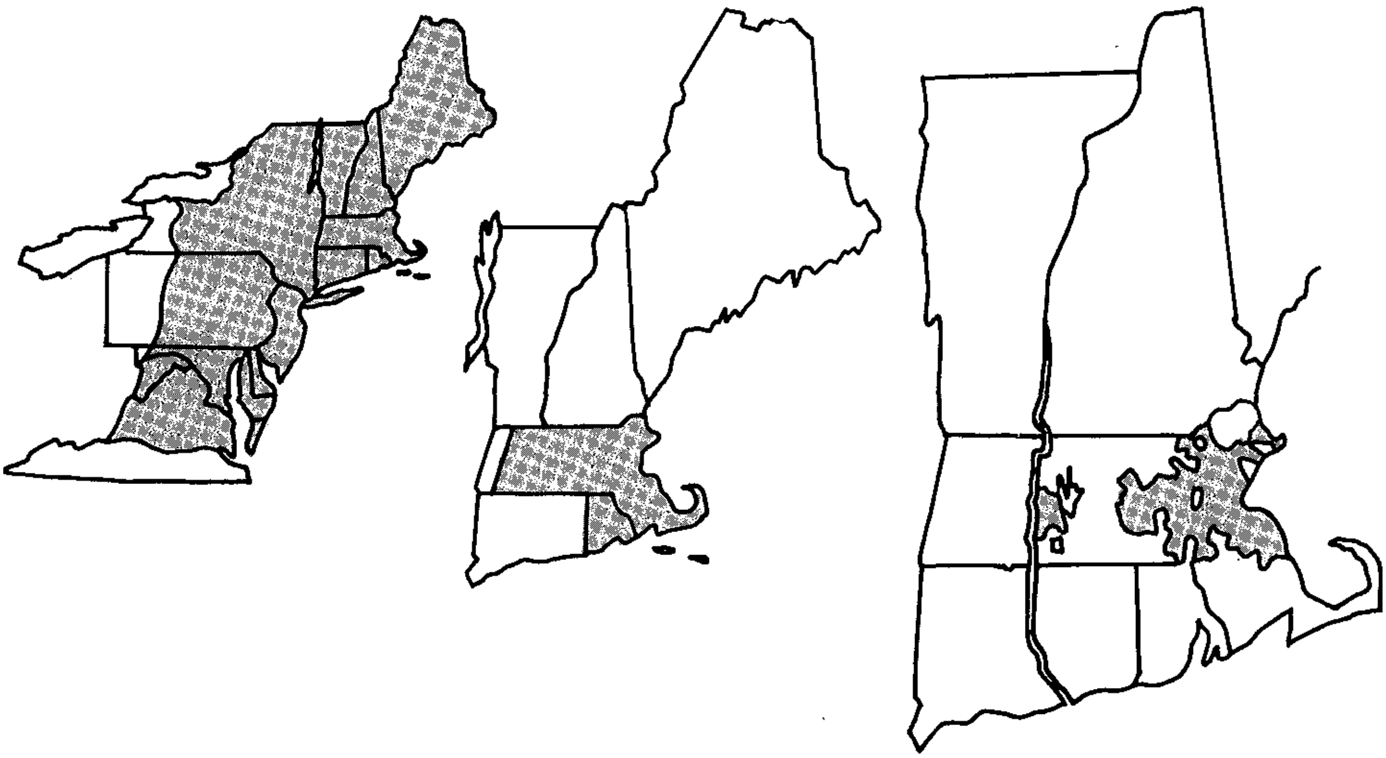
NORTHEASTERN UNITED STATES WATER SUPPLY STUDY

MILLERS RIVER BASIN WATER SUPPLY PROJECT

VOLUME I, MAIN REPORT



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OCTOBER 1974

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STATEMENT OF FINDINGS

MILLERS RIVER BASIN WATER SUPPLY PROJECT

1. I have reviewed and evaluated, in the best overall public interest, the documents concerning the Millers River Basin Water Supply Project, as well as the stated views of other interested agencies and the concerned public, relative to the various practical alternatives available to mee the short range water supply needs of eastern Massachusetts, recognizing the regional objectives set forth in P. L. 89-298, Title I - Northeastern United States Water Supply Study.

2. The possible consequences of these alternatives have been studied according to engineering feasibility, environmental, social well-being and economic effects, including regional and national development goals.

3. In evaluation, the following points were considered pertinent:

A. Environmental Considerations - From an environmental standpoint, I have selected the optimum plan which will afford more enhancement than adverse effects. The recommended project will have beneficial effects on water supply, water quality and aesthetics. From the outset, this study made a determined effort to evaluate the impact which the project might have on environmental quality. An analysis was made regarding possible impacts on the Connecticut River estuary, the Connecticut and Millers Rivers, and the receiving water storage reservoir. In general, impact caused by the diversion on the estuary and Connecticut River itself is expected to be minimal. The primary reason for this lack of environmental impact is the timing of diversions during high flow periods and the relatively small amount of water, when compared to river flow, which would be diverted.

Possible impacts caused by implementation of the project on the Millers River would be most pronounced at the confluence of the Tully and Millers Rivers in Athol, Massachusetts. However, in no case would the flow in the river be reduced below the established rate necessary to protect the river environment. Diversion would not affect ground water recharge or the ability of the river to meet water quality standards.

Some lessening of the Millers River "flushing" action and a slight temperature differential may occur with diversion. On the East Branch Tully River, reduction in flows, as on the Millers, is expected to cause minimal effects since diversion occurs during high flows in a relatively unpolluted stream.

In evaluating environmental impact on Quabbin and Wachusett Reservoirs, field and laboratory data included about 100 parameters, including chemical, physical, biological and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information and pollution abatement plans were considered and evaluated.

Within the receiving water body at Quabbin, the diverted flow may have impacts, but these possible impacts depend to a large degree on what engineering steps are taken prior to the actual diversion. For example, the present waste loads in the river may provide opportunities for algae growth or oxygen depletion. But when current pollution abatement schedules are followed as required by the Water Quality Act of 1972, present loadings in the river will be reduced; and as a consequence, the probability of possible damage to Quabbin also minimized.

If no additional water is made available to the reservoir, then increased demands will deplete available storage. Declining storage volumes in turn will cause an overall loss in water quality. In addition to this, possible reservoir water quality deterioration caused by reduced storage levels and supply shortages in the receiver area could also cause a loss in environmental quality for those communities served by the system.

Finally, if the project was implemented, the additional water supplied would cause a corresponding increase in waste water discharge. However, the Water Quality Act of 1972 calls for full treatment of waste discharges by the early 1980's; thus, minimal impact can be expected.

B. Social Well-Being Considerations - I find that the overriding social well-being consideration in the study area is the reduction of the water supply shortage hazard which could cause damages and curtail normal development in communities to be serviced. The recommended project will provide a high degree of reliability for meeting future supply needs. Since the project under consideration involved transfer of a resource through inter-basin diversion, impacts were investigated for both source and receiver areas.

In general, tangible impacts felt by source areas will be related principally to limited land taking and subsequent construction activity of short term duration. Apart from the few physical structures proposed, the natural character of the area will remain unchanged. The bulk of surface work will come in remote wooded areas with a minimum of disruption to local traffic patterns. Evidence of the tunnelling to Quabbin will be seen primarily as access shafts in three or four locations.

Apart from relatively small economic impacts, social impacts relating to supplier area residents' perception of equity are particularly significant and every effort was made to include these feelings in the plan formulation. The Millers River portion of the recommended plan in fact was a direct result of local public interest.

On the other hand, development of the recommended project would insure protection from water shortages and associated social and economic losses in the receiver communities. If the project was not implemented, social costs as well as economic costs could be expected.

C. Engineering Considerations - From an engineering standpoint, I have selected the project that would provide a high degree of protection and dependability against water supply shortages. Because the Millers River is presently polluted, there is some uncertainty as to the exact date the river will recover to drinking water quality. In order to minimize this risk, the recommended project includes as a component the East Branch Tully River, a good quality tributary of the Millers.

The present "state-of-the-art" concerning potential benefits and possible shortcomings of water demand conservation measures was also investigated closely. I believe such measures have not advanced to the point where they can be relied upon as an alternative to the proposed structural measures. I do feel, however, that the potential of certain conservation techniques warrants further study as a management tool in assuring wise use of available resources. Concurrent investigations on water demand, its make-up and opportunities for conservation measures, therefore, are recommended as a parallel effort to the project. Other considered project alternatives did not meet the criteria and requirements for economic, social and environmental reasons.

D. Economic Considerations - From an economic standpoint, I have selected the economically optimum plan by providing a high degree of protection from water supply shortages and enhancement of social well-being and economic growth. The recommended project will have a net effect of increasing employment, tax revenues and property values and will preserve and stimulate further growth in the protected area.

4. I find that the proposed actions, as developed in the Recommendations, are based on thorough analysis and evaluation of various practicable alternative courses of action for achieving the stated objectives; that wherever adverse effects are found to be involved, they cannot be avoided by following reasonable alternative courses of action which would achieve the Congressionally specified purpose; that where the proposed action has an adverse effect, this effect is either ameliorated or substantially outweighed by other considerations of national policy; that the recommended action is consonant with national policy, statutes and administrative directives; and that on balance the total public interest should best be served by implementation of the recommendations.

JOHN H. MASON
Colonel, Corps of Engineers
Division Engineer

MILLERS RIVER WATER SUPPLY PROJECT

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ACKNOWLEDGEMENT

This report was prepared by the Planning Branch of the New England Division, Corps of Engineers, Waltham, Massachusetts. The study itself was conducted under the general direction of Mr. John Wm. Leslie, Chief, Engineering Division, New England, and Mr. Harry Schwarz, Chief, Special Studies Branch, North Atlantic Division, New York. Mr. Joseph L. Ignazio, Chief, Planning Branch, was responsible for the technical direction of the investigation with staff assistance during the course of the study from Messrs. Lawrence J. Bergen, Paul E. Pronovost, John T. Smith, and Alan D. Randall.

The New England Division wishes to express its appreciation to those agencies who have participated in this challenging undertaking and have made available the services of many of their people. Special thanks are given to the Massachusetts Water Resources Commission; the Metropolitan District Commission; the New Hampshire Division of Economic Development and the Water Supply and Pollution Control Commission; and the Rhode Island Water Resources Board. Other Federal Agencies who have given generously of their time include the U. S. Geological Survey; U. S. Public Health Service; and the U. S. Fish and Wildlife Service and the Environmental Protection Agency.

The cooperation of interested citizens and water resources groups is also gratefully acknowledged. Special mention is given to the Citizens Participation Group and the Millers River Watershed Council, whose participation in the study provided valuable input to the report's recommendations.

1. Introduction

A. Background

The long-term normal rainfall in southeastern New England is about 42 inches per year. This "normal" condition is actually the average of many high and low rainfall years. When rainfall is below average for a period of time, the area experiences a drought. The recent drought of the sixties in southeastern New England caused many water supply systems to re-evaluate the dependable yield which their facilities could produce. In many cases, the new dependable yield was significantly less than previously estimated. In turn, water demands on these same systems have been increasing; therefore, additional supplies are necessary.

The drought began in 1961 and continued for seven years, with the severest deficiency occurring in 1965. During this period, an extreme drought condition existed in the northern half of New Jersey, northeast Pennsylvania, southeastern New York, all of Vermont and New Hampshire, parts of southern Maine, and the western half of Massachusetts. Within the region, the heavily industrialized and urbanized area extending from Boston to Washington was most severely affected.

The severity of the situation was caused by a combination of two factors -- a severe hydrologic adversity and the centering of the drought on the most densely populated region of the United States. In addition, many water supplies had been developed on the smaller upland prestine streams rather than on larger rivers with lower quality, but having a more dependable flow. Thus, the many cities and towns which relied upon upland sources were particularly hard hit by the drought.

At the height of the drought, major metropolitan regions surrounding Philadelphia and New York City faced mandatory restrictions in water use. Within Massachusetts, 85 cities and towns, including the two million customers of the Metropolitan District Commission, were asked to institute voluntary water rationing programs. Normal water use practices, such as lawn sprinkling and car washing, were sharply curtailed. In 23 Massachusetts' communities, emergency sources of water, sanctioned by the Public Health Department for temporary use only, were necessary to meet water needs.

In addition to affecting the water supply of almost 14 million people, the drought also had a severe impact on the environment. Low stream flow intensified pollution problems, affecting water quality and fish and wildlife. Algae blooms caused problems of taste and odor in water supplies and interfered with recreational use of lakes and reservoirs.

The prolonged sixties' drought thus caused extensive hardships on man and his environment. Fortunately, the years immediately prior to the advent of the drought were abnormally "wet" years. These "wet" years allowed many of the region's supply reservoirs to enter the drought period in a filled condition, precluding even more severe water use restrictions. There is no assurance, however, that the next drought, whenever it may occur, will be preceded by reservoir and aquifer filling "wet" years.

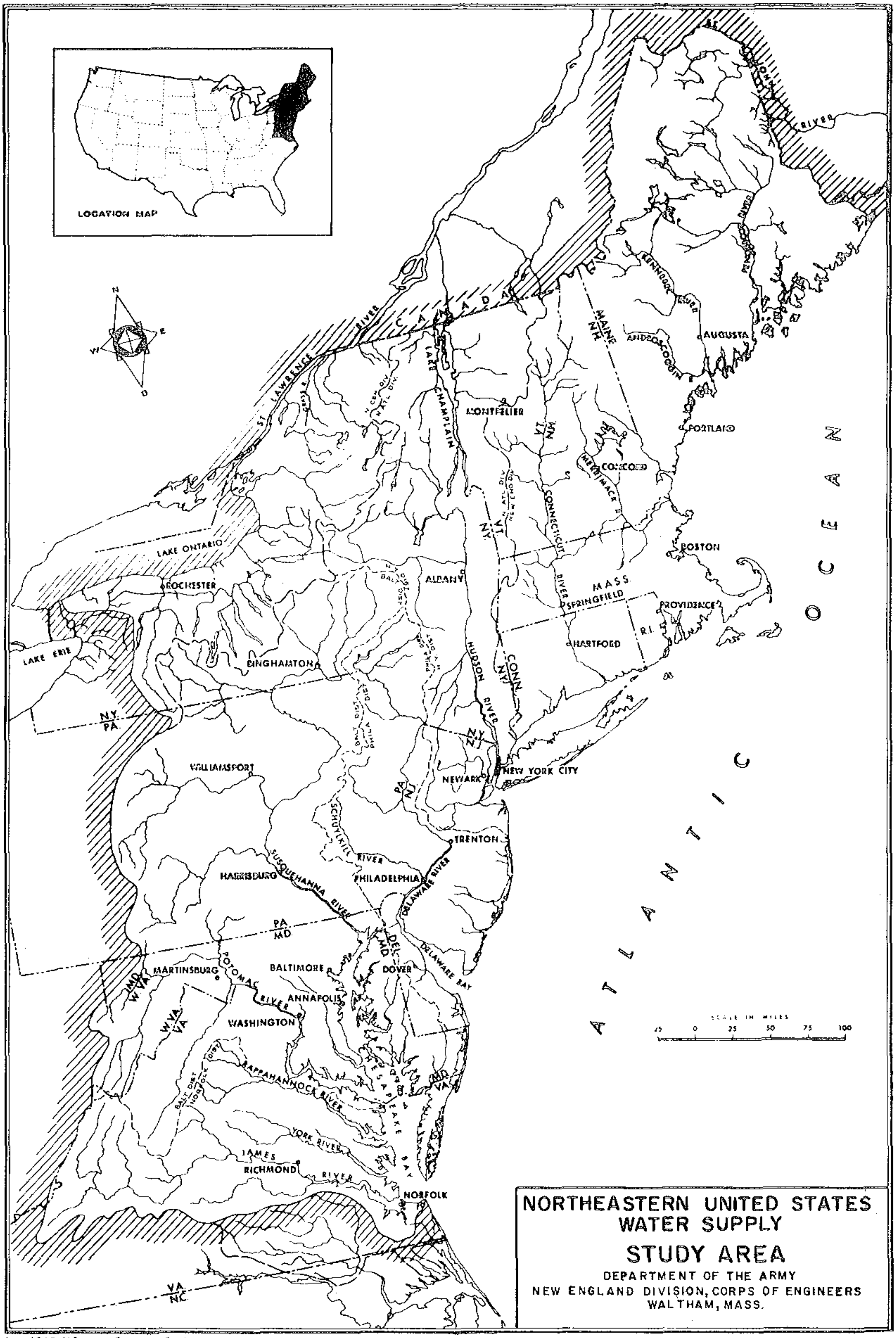
B. Authorization

The 89th Congress recognized that the assurance of adequate supplies of water for the great metropolitan centers had become a problem of such magnitude that the welfare and prosperity of the United States required the Federal Government to assist in its resolution. Consequently, the Congress enacted the Northeastern United States Water Supply (NEWS) Study on 27 October 1965, under Title I of Public Law 89-298.

The NEWS Study Act authorized the Secretary of the Army, acting through the Chief of Engineers, to prepare plans to meet the long range water supply needs of the Northeast, in cooperation with Federal, State and local agencies. The Chief of Engineers, in turn, assigned responsibility for the NEWS Study to the Division Engineer, North Atlantic.

C. Study Area

The NEWS Study Area includes those river basins within the United States which drain into Chesapeake Bay, into the Atlantic Ocean north of Chesapeake Bay, into the St. Lawrence River, and into Lake Ontario. The study area, therefore, includes all of Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Delaware, and the District of Columbia, and parts of New York, Pennsylvania, Maryland, Virginia and West Virginia. A plan of the area is shown on Plate No. S-1.



June 1969 · US Army, Corps of Engineers

PLATE S-1

With a watershed of approximately 200,000 square miles, the area contains a population of about 50 million persons, which is projected to reach about 85 million by the year 2020. Some 60 percent of the present population is concentrated in the five metropolitan areas of Boston, New York, Philadelphia, Baltimore and Washington; and the region includes twenty of the nation's one hundred largest cities.

Although the area has an average annual precipitation rate of about 40 inches, as compared to the national average of 30 inches, precipitation deficiencies in some parts of the area were up to 50 inches during the October '61 to December '65 period. The area's vulnerability to water shortage is revealed by the fact that some 14 million people, about 28 percent of the population, were restricted to some degree in their use of water during this drought. Although public awareness of the problems of water supply was increased by the drought experience, drought is not the only reason for concern. Available supplies of water of good quality will soon be inadequate, even under normal conditions, to meet the needs of the anticipated population and industrial growth.

D. Objective

The objective of the overall NEWS Study is the preparation of a coordinated general plan for essential water supply development in the Northeast which will recommend to the Congress an active program for Federal, State, local and private organizations. It thus provides a public forum where all vitally concerned with the water supply problems of the area can be heard in developing a plan to resolve one of the many domestic problems now facing the United States.

E. Methods

In achieving its objective, the NEWS Study will present a regional assessment of present and future water supply needs and will present alternatives for their solution. The study effort is being fully coordinated through the various Federal, State, local and private agencies and organizations. Such coordination assures that plans are consistent with, and integral to, other concurrent water resource planned development being formulated. During the study, interim reports will be prepared to deal with critical problems which may be encountered. These reports will contain specific recommendations to the Congress for authorization of major reservoirs, conveyance facilities, or treatment facilities, as may be appropriate. The Millers River Basin Water Supply Project, described later, is the result of the present interim report.

F. The Urgent Need Areas

The NEWS Study established the premise that areas whose present demand or projected 1980 demand exceed the present or anticipated capability of their water supply systems are classified by the NEWS Study as urgent. Under NEWS procedures, projects and regional programs for these urgent areas are being developed and made the subject of interim reports which will be submitted to the Congress for authorization. To identify these urgent areas, an initial appraisal, through reconnaissance studies, was made of the present system's capability to satisfy the projected 1980 demands. This appraisal included an evaluation of present system capabilities, present and projected domestic and industrial consumption, population expansion and economic growth. The appraisal disclosed four critically urgent areas as follows:

1) Eastern Massachusetts and Rhode Island

2) Western Connecticut - Metropolitan New York City and Northern New Jersey

3) South Central Pennsylvania

4) Metropolitan Washington, D. C.

Once these critical areas had been identified, feasibility detail studies were initiated to investigate alternative engineering solutions. The Western Connecticut area, although in the New England Division, because of its geographic proximity to the Metropolitan New York area, was studied in conjunction with that region. The second "urgent" need area within New England, Eastern Massachusetts and Rhode Island (Southeastern New England), was studied by members of the New England Division and is described in the following section. A plan of the Southeastern New England Region is given on Plate No. S-2.

Although, as described earlier, the NEWS Study area includes eastern seaboard states from Maine to Virginia, the subject of this interim report of survey is a project designed to meet a large portion of the critical supply needs within Southeastern New England. The following sections, therefore, focus on those NEWS Studies conducted to date within New England which led to the selection of the Millers River Basin project as a candidate for Congressional authorization. Similar reports in the other regions of the NEWS Study area are under way, and will be reported upon by the North Atlantic Division, Corps of Engineers.

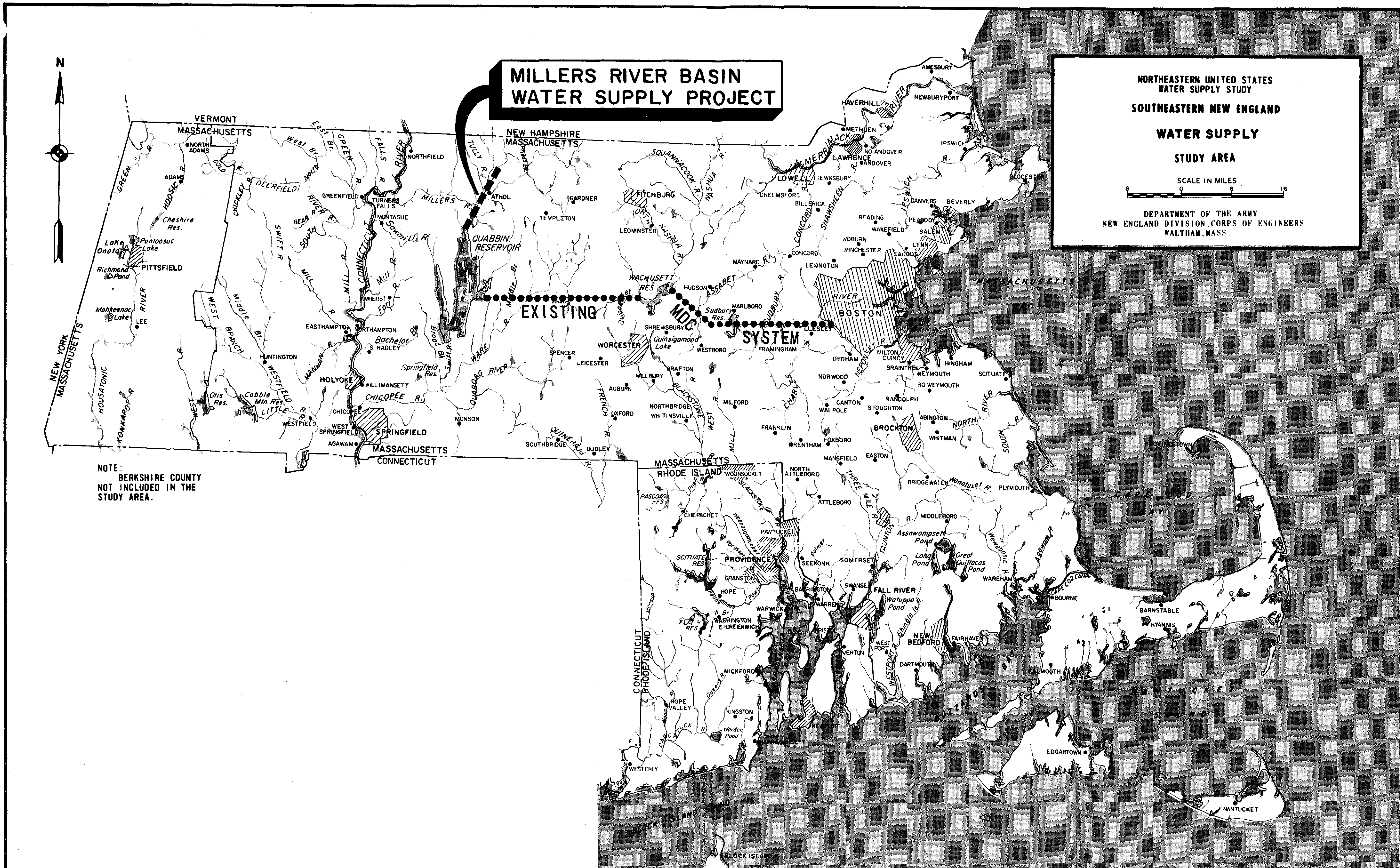

MILLERS RIVER BASIN
WATER SUPPLY PROJECT
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
SOUTHEASTERN NEW ENGLAND
WATER SUPPLY
STUDY AREA
SCALE IN MILES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
EXISTING MDC SYSTEM
NOTE:
BERKSHIRE COUNTY
NOT INCLUDED IN THE
STUDY AREA.
VERMONT
MASSACHUSETTS
NEW HAMPSHIRE
MASSACHUSETTS
NEW YORK
MASSACHUSETTS
MASSACHUSETTS
CONNECTICUT
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
RHODE ISLAND
QUABBIN RESERVOIR
BOSTON
WORCESTER
SPRINGFIELD
PROVIDENCE
FITCHBURG
LOWELL
LAWRENCE
HAVERHILL
BROCKTON
FALL RIVER
NEW BEDFORD
MASSACHUSETTS BAY
CAPE COD BAY
BUZZARDS BAY
NANTUCKET SOUND
BLOCK ISLAND SOUND

PLATE S-2

2. Southeastern New England

A. Reconnaissance Studies

The New England Division, at the request of the North Atlantic Division, began work on the NEWS Study within the New England area in 1967. First, major metropolitan areas, such as Boston, Worcester, Springfield, New Bedford, Fall River, Providence, Bridgeport, New Haven and the tri-city region of New Hampshire (Nashua - Manchester - Concord) were investigated to determine if their present systems could meet the expected water demand in 1980. This appraisal disclosed two "urgent need" areas within New England. The first, Western Connecticut, because of its geographic proximity to the Metropolitan New York area, was studied in conjunction with that region. The Eastern Massachusetts and Rhode Island area was also classified as an "urgent need" area, and the staff of the New England Division initiated a twelve-month engineering feasibility study in December 1968.

B. Feasibility Study

Following completion of reconnaissance studies on the water supply situation within Southeastern New England, a feasibility study on possible engineering solutions was undertaken. The objective of this investigation was to formulate feasible engineering alternatives for a regional water supply for the study area. In achieving this objective, the evaluation of alternatives was prepared without regard to the institutional restraints -- legal, economic or organizational -- so that all physically feasible projects could be evaluated.

The feasibility study area falls within the boundaries of the so-called "megalopolis" which extends from Boston, Massachusetts to Washington, D. C. Following the general trend of population growth within the megalopolis, the population within the Southeastern New England region is expected to increase at a steady rate from a 1970 total of 6.5 to 7.8 million in 2000 and to 9.7 million by 2020, or an increase of 49 percent. The largest increases, however, are most likely to occur around the urban centers of Boston and Providence.

Water use from public water supply systems in the region has increased dramatically since the turn of the century. Increases in population and productivity, movement to urban regions, and rises in per capita usage are important factors in this increase in demand from public water supply utilities. Forecasts of future demands were made utilizing past trends of water use, modified to reflect expected increases in industrial reuse and possible decreases in the proportion of domestic use. Average water demands in the study area could rise from a 1970 total of 850 million gallons per day to about 1300 million gallons per day in 1990 and almost 2100 million gallons per day by the year 2020.

At present, there are a total of 369 public water supply systems within the region. The aggregate developed yield or water available for consumers from these systems totals about 1,000 million gallons per day. The largest regional system within the area is the Metropolitan District Commission system, which services either wholly or partially the water supply needs of 41 municipalities with a population of about 2,000,000. The average daily consumption of these communities in 1971 was 322 million gallons per day, while the safe yield of the system is estimated to be 300 million gallons per day. If this system and others in the region are to provide the anticipated demand without major modifications of consumer water use habits, then large quantities of new supplies are needed.

Nine major river basins were investigated to determine their potential in meeting the previously described water supply needs. Included were the Connecticut, Merrimack, Ipswich, North, Taunton, Pawtuxet, Blackstone, Pawcatuck, and Thames River Basins. A plan showing the location of the basins is given on Plate No. S-3. Also, ground water resources were assessed for regional use and for local potential development. Other techniques such as desalination, waste water reuse, and weather modification were evaluated for their role in augmenting regional water supply systems.

From a regional view, available water resources were identified in sufficient quantities to meet forecast water demands even beyond the year 2020. Potential supply problems within the region thus are not occasioned by a scarcity of resources, but rather by the lack of facilities which develop the resource. Water supply problems within the region arise from shortage of developed facilities, shortage of suitable sites for new facilities, and competing alternative uses for land and water resources.

Twenty-eight regional projects, shown on Tables S-1 and S-2, were described in the feasibility report as possible engineering solutions.

TABLE S-1

POTENTIAL PROJECTS REPORTED UPON IN FEASIBILITY REPORT
TO MEET 1990 SUPPLY NEEDS

Basin	Project Name	Yield (mgd)	Method of Development	Construction Cost (1 x 10^6 \$)[1]	Annual Cost (dollars/mg)[1]
Connecticut River	Tully	55	High Flow Withdrawal	25.3	93
	Northfield Mountain	125[2]	High Flow Withdrawal	37.9	91
	Hadley	125	High Flow Withdrawal	60.5	141
	West Deerfield	125	High Flow Withdrawal	74.6	154
Merrimack River	Merrimack - No. Middlesex	35	Direct and High Flow Withdrawal	18.1	131
	Merrimack - No. Middlesex - Essex	50	High Flow Withdrawal	36.4	165
	Merrimack - E. Massachusetts	230	High Flow Withdrawal	146.5	141
Ipswich River	Ipswich River Reservoirs	15	High Flow Withdrawals and Storage	15.8	224
North River	North River Reservoir	25	Storage	18.1	151
Taunton River	Lakeville Ponds	25	High Flow Withdrawal	45.7	288
	Copicut Reservoir	25	High Flow Withdrawal and Storage	64.0	403
Pawtuxet River	Big River Reservoir	29	Storage	45.9	322
Massachusetts Ground Water	Plymouth County Ground Water - No. Plymouth	12	Withdrawal from Ground Water Aquifer	20.2	423
	Plymouth County Ground Water - Bristol County	28	Withdrawal from Ground Water Aquifer	48.9	378

[1] 1969 Feasibility Study Costs Updated to 1972 Price Level.

[2] Based on a downstream control flow of 10,000 cfs at Turners Falls, cost figures differ from values in this report because of the greater detail used here.

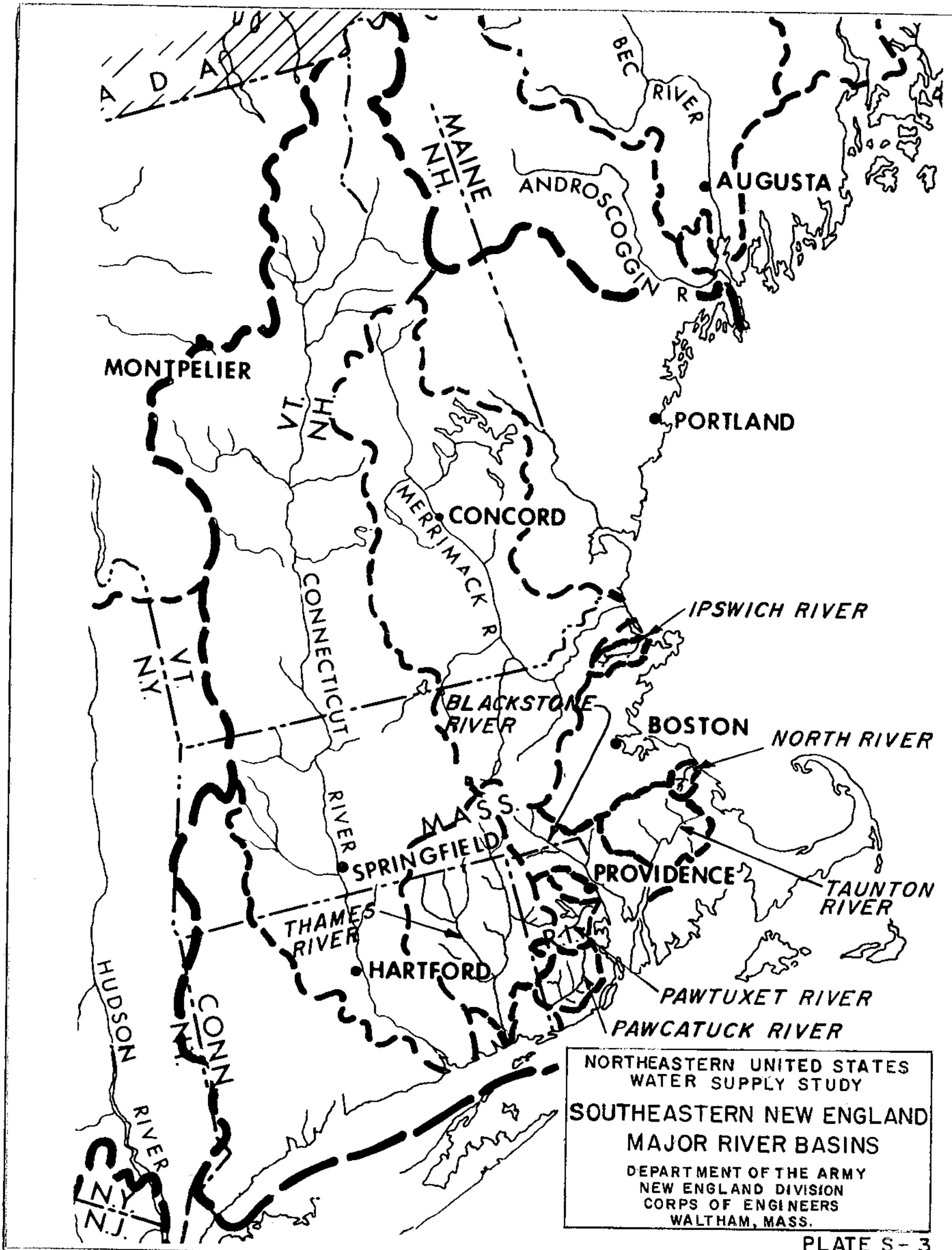
TABLE S-2

POTENTIAL PROJECTS REPORTED UPON IN FEASIBILITY REPORT TO MEET 2020 SUPPLY NEEDS

Basin	Project Name	Yield (mgd)	Method of Development	Construction[1] Cost (1×10^6 \$)	Annual Cost[1] (dollars/mg)
Connecticut River	Hadley - A	500	High Flow Withdrawal	595 (495)[2]	253 (219)[2]
	Hadley - B	550	High Flow Withdrawal	615 (523)[2]	237 (213)[2]
	Knightville Reservoir	20	Storage	35.4	218
	South Hadley	40	Direct Withdrawal	19.7	141
Merrimack River	Lowell - A	500	Direct and High Flow Withdrawal	452 (398)[2]	191 (176)[2]
	Lowell - B	550	Direct Withdrawal	468 (427)[2]	178 (168)[2]
Combined Connecticut & Merrimack Rivers	Lowell - So. Hadley - A	500	Direct and High Flow Withdrawal	465 (421)[2]	200 (186)[2]
	Lowell - So. Hadley - B	550	Direct and High Flow Withdrawal	489 (445)[2]	194 (183)[2]
Taunton River	Taunton River Estuary Dam	97	Storage and Direct Withdrawal	80.2	183
Pawtuxet River	Flat River Reservoir	13	High Flow Withdrawal	9.7	203
Thames River	Moosup River Reservoir	20	Storage and High Flow Withdrawal	23.1	290
Pawcatuck River	Wood River Reservoir	30	Storage and High Flow Withdrawal	30.0	247
Blackstone River	Nipmuc and Tarkiln Reservoir	14	Storage and High Flow Withdrawal	23.0	302
Pawcatuck Ground Water	So. Central Rhode Island	11	Withdrawal from Ground Water Aquifer	9.4	236

[1] 1969 Feasibility Study Costs Updated to 1972 Price Levels.

[2] Based on earlier (1990) Merrimack River Development.



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

SOUTHEASTERN NEW ENGLAND
MAJOR RIVER BASINS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE S-3

C. Events Leading to Project Selection

The feasibility report on possible engineering alternatives for meeting future water supply needs within southeastern New England was completed in November 1969. Draft copies of the report were then distributed for comments by other agencies with responsibility in water resource planning and implementation.

Other Federal Agencies receiving review drafts included the Departments of: Interior; Agriculture; Health, Education and Welfare; Housing and Urban Development; and Commerce.

Draft copies were also sent to the six New England State Coordinators whose offices had been designated by the respective State Governors as state clearing houses for the NEWS Study. These state coordinators in turn distributed the reports to State Agencies which could provide input as review comments.

Established Regional Planning Agencies in the New England States received review copies and were asked to forward their comments through the State Coordinators.

Following the receipt of comments from the various agencies, a meeting was scheduled by the North Atlantic Division in Boston, Massachusetts, for 7 May 1970. The objectives of this meeting were as follows:

(1) To present and discuss the various alternative water supply projects reported upon in the feasibility study. Included in this element was a description of an alternative technique for diverting excess flows from the Merrimack River without upstream augmentation reservoirs and the need for implementing a pollution abatement program to insure adequate water quality.

(2) To discuss the need for and scope of an environmental impact study of the various engineering alternatives.

(3) To select one or more of the engineering alternatives for which more detailed studies in engineering, economic evaluation, environmental and social impact might be undertaken as NEWS Studies.

In a broader sense, the objective was to assure adequate supplies of water for the region in the most beneficial manner possible; i. e., with the optimum overall economic, environmental, and social impact on the region and the country as a whole. Flexibility, reliability and timeliness are some of the selection criteria used to maximize these components. Political and institutional tendencies and existing laws or statutes act, with varying degrees of rigidity, as constraints in project selection.

Attendees at the meeting varied from Federal and State Agencies to private organizations such as the Audubon Society. A complete list of organizations in attendance is as follows:

Massachusetts
- Metropolitan District Commission
- Division of Water Resources
- Division of Fish and Game
- Division of Marine Fisheries
- Water Resources Commission
- Department of Public Health

Connecticut
- Water Resources Commission

Rhode Island
- Water Resources Board

New Hampshire
- Water Supply and Pollution Control Commission
- Water Resources Board

New England River Basins Commission

United States Department of the Interior

United States Public Health Service

Office, Secretary of the Army

United States Army, Corps of Engineers
- Office, Chief of Engineers
- North Atlantic Division
- New England Division

New England Natural Resources Center

Massachusetts Audubon Society

City of Boston

Anderson Nichols and Company

Union of Concerned Scientists

At the outset of the meeting, a Corps of Engineers representative stated that the NEWS Study was prepared to undertake detailed investigations on potential water supply projects in southeastern New England. These projects, if authorized and constructed, would then aid in meeting the short range "urgent" water supply needs of the region.

The Corps of Engineers spokesman noted, however, that available funding and manpower did not allow for detailed analysis of each alternative project. Therefore, the various agencies and organizations present were requested to state their views on those projects for which immediate detailed studies might be undertaken. By this manner, it was felt that the Corps of Engineers could then proceed with those projects which would efficiently utilize available funds to study projects with maximum relief to the region.

Discussion at the meeting ranged from engineering and environmental considerations of the various possible alternatives to concern with socio-economic impacts. At the end of the meeting, consensus on a number of detailed studies, which should be initiated immediately, was reached. These projects selected from the many potential alternatives described in the feasibility report are as follows:

(1) The Corps of Engineers should proceed with detailed studies on the development of Tully Reservoir.

(2) The Corps of Engineers should consider the Northfield Mountain Water Supply Project as a very viable element in any regional water supply plan for southeastern New England. Accordingly, the Corps should initiate detailed studies on this project and these studies should be designed to complement those already under way or planned by the Metropolitan District Commission.

(3) The Corps of Engineers should conduct studies on the possibility of using the Merrimack as a regional source of water supply and concomitant studies on requirements for improving its quality.

(4) The Corps should conduct a broad environmental impact study of all alternatives proposed for southeastern New England.

(5) The Corps should conduct a detailed study specifically directed at determining the effects of upstream diversion on the estuaries of both the Merrimack and Connecticut Rivers.

(6) The Corps should explore the possibilities of advanced site acquisition, beginning in the State of Rhode Island.

Utilizing the selected work items as a basis, the NEWS work program for southeastern New England was constructed. One of the projects selected at the May 1970 meeting, namely, the Millers River Basin Water Supply Project, is the subject of this report.

D. Other Areas Requiring Early Attention

The projects selected for detailed studies, as described in the previous section, would provide a large input towards supplying short range water needs in southeastern New England. Even if the projects undergoing detailed investigations, such as the Millers River Basin Water Supply Project, were constructed, other areas within the region will require early augmentation of available supplies.

As illustrated in the graph displayed on Plate No. S-4, implementation of the Millers River Basin and its companion report, Northfield Mountain, projects would provide 148 million gallons per day of additional supply.

Total forecast short range additional (1990) water needs, however, within southeastern New England are estimated to be about 316 million gallons per day, while additional long range (2020) needs may total about 1,084 million gallons per day. Thus, although the Millers River Basin and its companion report (i.e. Northfield Mountain) will contribute significantly toward meeting both short and long range needs, other projects will be necessary.

As a means of meeting a portion of these other need areas, the NEWS Study is presently preparing an Interim Report of Survey on the potential development of the Merrimack River as a supply source. The possibility of such development was an element agreed upon at the May 1970 meeting as requiring detailed analysis.

Since present water quality in the Merrimack River is poor, an investigation[1] of alternatives for managing wastewater in the basin was the

[1] The Merrimack: Designs for a Clean River: Alternatives for Managing Wastewater in the Merrimack River Basin, September 1971, prepared by Northeastern United States Water Supply Study.

first study undertaken by the NEWS Study. A follow-up Interim Report of Survey on possible wastewater treatment plants in the Massachusetts portion of the basin is now being conducted.

The completion of the water supply and wastewater studies presently under way will identify the potential which the Merrimack River Basin has in meeting water supply needs not met by the Northfield Mountain and Millers River Basin Water Supply Projects.

Other areas slated for detailed investigation include the Providence, Rhode Island Metropolitan Region; the Ipswich River Basin; northern Plymouth County and southeastern Massachusetts. Completion of all these detailed studies and implementation of recommended projects would insure adequate supply for the entire southeastern New England region.

3. Summary of Selected Project -- Millers River Basin Water Supply Project

A. Water Supply Setting

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population.

The sixties' drought, which began in 1961 when precipitation and water levels fell below normal, ultimately directly affected the water use patterns of more than 20 million people. In 1965 alone, drought related water shortages and associated problems were severe enough to warrant emergency actions by local, state and Federal agencies. Within Massachusetts, 85 cities and towns imposed restrictions on water use.

Historically, within the study area, public water supply has been furnished through municipal level utilities. In 1965, there was a total of 369 public water systems servicing water needs of the region. Population served by these suppliers varies from less than one hundred to more than two million for the largest system, the Metropolitan District Commission (Boston).

During and following the drought, a number of communities conducted engineering studies to determine methods for augmenting their existing supplies. In some cases, new supplies have been developed by municipalities which would allow them to meet supply needs.

As a supplement to the actions taken by the local and regional supply agencies, regional planning agencies have been active in evaluating the various systems' capability to meet future supply requirements. Investigations conducted by the local water utilities, the regional planning agencies and the NEWS Study all indicate that additional supplies are necessary if the short range needs are to be met.

In this Interim Report of Survey, three[1] major groups of communities which could be serviced by the addition of the Millers River Basin Water Supply Project have been identified. These are:

(1) Forty-one communities which are presently serviced by the Metropolitan District Commission (Boston), the largest regional system in the study area.

[1] Background data contained in Appendix B - Future Population and Water Demand Studies.

(2) Twenty-four communities which the various local and regional planning agency studies identified as having no reported future source of supply except connection to the MDC system.

(3) Sixty-six communities which have reported local resource potential to meet short range (1990) needs. As an alternative to further local resource development, these communities could also attempt to join the existing regional system.

The municipalities included in the first two categories above are considered for purposes of this report to be the probable 1990 service area which would utilize the supply made available by the Millers River Basin Project. Existing and proposed dependable yield of these cities and towns is estimated to be about 383 million gallons per day. Total 1990 water supply requirements on the other hand are estimated to be about 524 mgd, thus forecast water deficits could total about 141 mgd.

The Millers River Basin Water Supply Project would add an estimated 72 mgd to the available supplies. Implementation of the Millers River Basin Project, therefore, would provide about half of the estimated 1990 supply deficit of the serviced communities. In order to meet the total deficit, another source of supply must be developed. The Northfield Mountain Project in north-central Massachusetts is a candidate for development for this needed supply and is the subject of a separate report.

The sixty-six communities listed in category (3) as possessing sufficient local resource potential to meet 1990 needs were considered for purposes of this report as a "possible" service area. The focus of present planning by these municipalities, however, appears directed toward development of these local resources rather than connection to the existing regional system. Therefore, it is not considered likely that these communities will join the system in the short range.

In summary, certain groups of communities (particularly those outside Metropolitan Boston) can satisfy their present and projected 1990 needs without relying directly on the MDC. However, they cannot do so unless the MDC supplies certain key communities. It, therefore, becomes apparent that any concept of regional supply for the eastern Massachusetts - Rhode Island Study Area depends on firming up the existing regional system i.e., the MDC. This is the specific problem addressed by the present survey report.

Also by 1990, many eastern Massachusetts communities not served by the MDC will collectively require water in addition to that available in their immediate watersheds. The development of institutions and physical systems to cope with this regional problem is critical. By 2020, the MDC will also require additional water from a large regional source. These two problems are the subjects of on-going studies.

B. Description of Projects

1) General

The possibility of diverting water from the Millers River Basin to Quabbin Reservoir appears to offer a viable method of providing the supply within the time limits imposed by the needs. Within this study, considerations included: the preliminary design of diversion facilities; delineation of those communities which may require the additional water; evaluation of the effects of the project on the environment and measurement of the socio-economic impacts which the project may have.

The Millers River Basin projects will use the large existing storage capacity of Quabbin Reservoir, thus allowing a high-flow skimming technique; that is, flow would be diverted during high flow periods, principally during spring run-off. In evaluating the potential yield from the alternative projects, consideration has been given to allied water resource uses downstream of the diversion locations. Flow rates below which diversions of Millers River tributary waters would not take place have been established. These flows are based on both water quality and fish and wildlife needs.

As a second means of control, diversion would not occur if flow in the Connecticut River at Montague City gaging station was less than 17,000 cubic feet per second or about 11,000 million gallons per day. This control flow is specified in current Massachusetts State Legislation regarding the Northfield Mountain Project.

2) Alternative No. 1 - Millers River Diversion

The potential of diverting water from the Millers River to Quabbin Reservoir was recognized even prior to the construction of the reservoir. Thus, when the reservoir was designed and constructed in the 1920's and 1930's, the storage capacity was intentionally developed larger than the natural drainage area might require. With this historic precedence, diversion from the mainstem Millers River, therefore, was one of the alternatives investigated.

At present, the Millers River mainstem is highly polluted. There are six major sources of pollution upstream from Athol, which include four municipal and two industrial sources. The Otter River receives wastes from Gardner, Baldwinville, Seaman Paper Company and Baldwinville Products Company; and the Millers River, from Winchendon and South Royalston. The remainder of the watershed is basically forested with individual homes, small farms and an occasional small business. The major sources of pollution in the basin above Athol are the two paper mills located on the Otter River. All of these pollution sources cause the Otter River and the Millers River from its confluence with the Otter River to be of unsatisfactory quality.

As it exists at present, then, diversions for water supply purposes cannot be considered because of water quality problems. A report prepared by the Metropolitan District Commission for the Massachusetts State Senate in 1967 bears out this conclusion. In that report, it was noted that the Millers River mainstem would require "elimination of sewage and manufacturing wastes before consideration could be given to these sources for water supply purposes."

However, cognizant of the Massachusetts and Federal Pollution Abatement schedule, we attempted to forecast the effect of pollution abatement on its plans. Based on our evaluation, it appeared that the river, even after proposed secondary treatment "clean up," would require additional or advanced waste treatment at the point sources of pollution. This additional treatment, over and above that presently planned, is thought necessary to insure good quality water which would not be injurious to either public health or to the environmental quality of Quabbin Reservoir.

In this alternative plan, an intake structure would be constructed on the north bank of the Millers River, about 3 miles upstream from the confluence of the Tully with the Millers River, in the Town of Athol, Massachusetts. A combination bascule gate and weir regulating structure to control water withdrawn into the intake would also be constructed at this location.

Water diverted from the river would enter the intake shaft to a 7 mile, 10 foot diameter deep rock tunnel aqueduct and then conveyed to Quabbin Reservoir.

Land requirements for this plan would involve about 40 acres on the mainstem Millers River to allow for the construction of the facilities and for the small intake regulating pool. The river diversion structure would incorporate bascule gates to allow the 5 foot regulating pool to be maintained only during diversion periods.

Additional yield which could be made available by this alternative would be about 68 million gallons per day on an average annual basis. Cost estimates for the advanced waste treatment facilities, intake works, tunnel and outlet structure would total about 39 million dollars.

This alternative would have a positive effect on the Millers River area as the river would become a clean, non-odorous water body. The streams then could be the recreation center of the area affording fishing, swimming, and other water oriented opportunities. There might be, however, a slight temperature rise, a lessening of the sediment load, and a partial loss in flushing action on the Millers River downstream of the diversion site. On the Connecticut, because of the small change in flow (1 - 2%), minimal impacts are expected.

Until the actual "clean up" of the river occurs and the water tested and evaluated, the effect of the diversion on Quabbin will be questionable. If, however, the river reacts positively, then there would be little problem within Quabbin.

3) Alternative No. 2 - Tully-Millers Diversion

This alternative, as Alternative No. 1, would divert water from the mainstem Millers River after completion of the proposed waste treatment facilities and the advanced waste treatment plants proposed as part of this plan. In addition, water would be diverted from the East Branch Tully River drainage area, presently controlled by the existing Corps of Engineers flood control reservoir.

Facilities needed for this alternative include advance waste treatment plants on point sources of pollution upstream from the proposed intake on the Millers River. An intake structure for the East Branch of the Tully River would be constructed adjacent to the existing outlet channel of the Tully Flood Control Dam. This structure would consist of a combination bascule gate and inlet weir control to a morning glory type intake to the tunnel aqueduct. An 8 foot diameter tunnel would then be constructed to the Millers River, about 3 miles upstream from the confluence of the Tully with the Millers River in the Town of Athol.

At the Millers River, intake facilities similar to those described in Alternative No. 1 would be constructed. From this intake, water from the Millers River would join that water from the East Branch Tully River and the flow would be conveyed to Quabbin Reservoir via a 7 mile, 10 foot diameter tunnel.

Land requirements for this plan would involve about 40 acres on the mainstem Millers River to allow for the construction of the intake facilities and a small regulating pool. At the Tully intake, no land would be required as the facilities considered at that location would be constructed on lands that are presently Federally owned.

Additional yield which could be made available by this alternative, using the flow constraints described earlier, would be about 76 million gallons per day on an average annual basis. To achieve this yield, maximum diversion rates from the East Branch Tully and Millers Rivers would be 490 and 730 cubic feet per second, respectively.

Cost estimates for the advanced waste treatment facilities, intake works at the East Branch Tully and Millers Rivers, tunnel aqueduct from Tully to Quabbin, and the outlet works at Quabbin would total about 49 million dollars. This alternative offers a solution not only to meet short, but medium range water needs forecast for communities served by the Quabbin - Wachusett Reservoir system.

This alternative would have the same effects of the Millers and Connecticut Rivers as Alternative No. 1. The only difference would be the reduction in flows from the East Branch Tully River. Minimal impacts on this stretch of river are anticipated, however. The project would still provide a clean Millers River with important new recreation and land use opportunities.

Questions still would remain on the effect of the Millers River water on Quabbin Reservoir until the actual "clean up" can be tested and evaluated. But our studies indicate that the East Branch Tully River is presently of adequate water quality to be diverted to Quabbin Reservoir.

4) Alternative No. 3 - Tully Complex Diversion

Because of the questions regarding the results of the Millers River "clean up," diversions from tributaries of the Millers River were also investigated. Based on analysis of data, the quality of some of these tributaries is suitable for use as a water supply source.

As in both Alternatives No. 1 and 2, diversion periods for this plan would be contingent upon flow rates in both the Connecticut River and in the tributaries themselves.

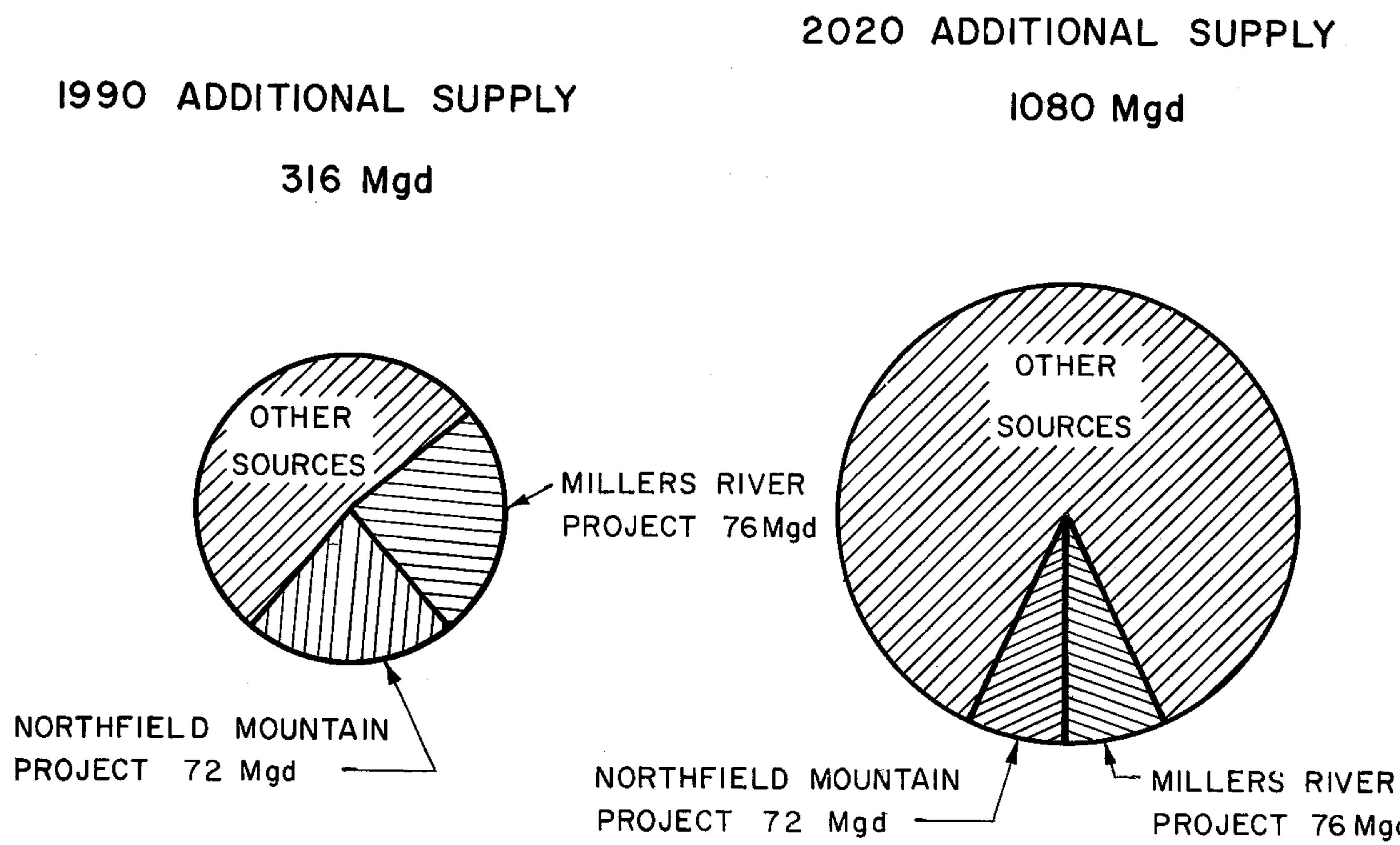
In this alternative plan, an intake structure and pumping station would be constructed on the west bank of Tarbell Brook in the Town of Winchendon. To control inflow to the pumping station, a concrete weir structure, 9 feet high, would be constructed across the brook. Water withdrawn would be conveyed westerly to Priest Brook via a 48 inch diameter pressure conduit. The route of the conduit for most of its length would fall within the existing right of way of Royalston Road. Maximum capacity of the pumping facility for this transfer would be 90 cubic feet per second.

At Priest Brook, water flowing from its natural drainage area plus the supplemental flow from Tarbell Brook would be collected and pumped via a 72 inch diameter conduit with a 120 cubic feet per second capacity to the East Branch Tully River. In order to reduce the transmission capacity from Priest Brook to the East Branch Tully, a regulating storage reservoir about 30 feet high would be constructed on Priest Brook. This reservoir would inundate seasonally about 400 acres and would be drawn down as soon as possible following the diversion period.

At the existing Tully Flood Control Reservoir, water from its natural drainage area plus that from Tarbell and Priest Brooks would be withdrawn via an 8-1/2 mile, 8 foot diameter tunnel to Quabbin Reservoir. As an aid in economically minimizing the size of the Tully - Quabbin aqueduct, this alternative would utilize about two inches of runoff storage of the existing flood control storage at Tully. The inundated area in the reservoir thus would be about 600 acres.

The Tully - Quabbin aqueduct would have additional flow added to it by means of a conduit from the West Branch of the Tully River. Facilities required on the West Branch would consist of a regulating storage pool created by an 11 foot high concrete weir structure and a pumping station capable of transferring 90 cubic feet per second. The pool created by weir structure would inundate about 13 acres.

Land requirements for this plan would involve about 7 acres in Winchendon, Massachusetts, in the vicinity of Tarbell Brook for the conduit right of way; about 1056 acres for the Priest Brook Reservoir; about 165 acres located in Winchendon, Massachusetts; and



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

ADDITIONAL WATER SUPPLY NEEDS SOUTHEASTERN NEW ENGLAND AREA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE S-4

about 891 acres located in Royalston, Massachusetts. In addition, about 4 acres in right of way easements for the Priest Brook - Tully conduit would be necessary.

No additional land would be required at Tully Reservoir itself since this land is currently in Federal ownership. On the West Branch Tully River, approximately 36 acres would be needed for construction of the diversion facilities. Almost all of the land for the West Branch works would be located in Orange, Massachusetts, although a final design on the conduit and aqueduct could require a small amount of land for conduit right of way in Athol, Massachusetts.

Additional yield which could be made available by this alternative would be about 48 million gallons per day on an average annual basis. Cost estimates for the intake works, pumping stations, various impoundment structures, conduits and tunnel aqueduct and outlet structure would total about 49 million dollars.

The impoundments on Priest, Tarbell and West Branch Tully River, because of their size and operating procedure, would afford limited recreational development. At Tully Lake, the recreation potential is excellent with hiking, camping and swimming facilities planned.

The effect on the environment of Alternative No. 3 is expected to be greater than the other two because of the impoundments. The diversion, however, would have little effect on the water quality of the Millers since the diversion would occur at high flow periods, and water quality standards are based on low flow conditions. Minimal impacts, as with Alternatives No. 1 and 2, are envisioned for the mainstem Millers and Connecticut Rivers. Presently, this tributary water is of adequate quality to be diverted to Quabbin Reservoir, since the Ware River is of similar quality and has been diverted for 30 years.

C. Project Selection

In the formulation and selection of plans, a determined effort has been made to involve the public in the decision-making process. Progress, information and public meetings were held throughout the conduct of the study. Audience input gained at these meetings contributed significantly to the work. The Millers River portion of the recommended plan, in fact, was a direct result of local public interest.

On the basis of the investigations conducted in this study on the three Millers River Basin Diversion Alternatives; namely,

Alternative No. 1	Millers River Diversion
Alternative No. 2	Tully-Millers River Diversion
Alternative No. 3	Tully Complex Diversion

the most advantageous plan for both the communities within the source area as well as those municipalities which would use the water is Alternative No. 2. Some of the advantages of this plan include:

1) This project's economic costs are fully competitive with the other alternatives.

2) This plan provides for a larger multiple use prospect, and a cleanup of the Millers River would be beneficial to communities in the Basin. A clean river water, even after diversion, would provide an opportunity for use of the river for water supply, recreation, fishing and other outdoor activities long denied because of the river's pollution.

Cleanup of the river includes advance wastewater (tertiary) treatment at pollution sources, providing a river of higher quality than is presently anticipated, even after the planned waste treatment program is implemented.

3) Yield for water supply purposes could be greater than Alternative No. 1 or 3, and would consequently meet needs of serviced municipalities through a longer time frame.

4) Any possible environmental damage to the river should be largely offset by the river cleanup program along with the opportunities for environmental enhancement which presently do not exist.

5) Use of the East Branch Tully River water as part of the project would minimize the "risk" that the mainstem water, even after cleanup, because of the river's natural reaction, may not be available when needed. East Branch Tully River water will allow adequate time for testing, monitoring and evaluation of the Millers River water prior to its diversion.

6) Land requirements for necessary facilities and changes in land use patterns caused by the project are held to a minimum. About 40 acres of land would be required for the Millers intake and

tunnel shafts, beyond that the land required is already in public ownership. There is a possibility that an additional 5 acres for rock excavated from the tunnel may be necessary; but such need would be a detailed design consideration.

7) Major negative socio-economic impacts forecast for the municipalities to be serviced by the diversion will be avoided.

8) Natural flows in tributary streams, except East Branch Tully, as well as the Millers River upstream of the diversion intake in Athol, will not be altered.

D. Impact Analysis of Alternative No. 2

The evaluation of the project's impacts was accomplished using the three account system developed by the Water Resources Council. Under the Council's proposed guidelines, the overall purpose of the project is measured with regard to enhancing National Economic Development, Environmental Quality and Regional Development.

In order to assess the project's impacts, studies on engineering, socio-economic [1] and environmental [2] considerations were examined. Since the project under consideration involved transfer of a resource through inter-basin diversion, impacts were investigated for both source and receiver areas.

Impacts are quantified and translated into dollar values where possible. In those cases where impacts are not quantifiable, the effects of the project are discussed such that the reader will be aware of all the ramifications of implementing the project.

In general, tangible impacts felt by source areas will be related principally to limited land taking and subsequent construction activity.

Apart from the few physical structures proposed, the natural character of the area will remain unchanged. The bulk of surface work will come in remote wooded areas with a minimum of disruption to local traffic patterns. Evidence of the tunneling to Quabbin will be seen primarily as access shafts in three or four locations and spoil disposal sites which have not yet finally identified.

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1 Background data contained in Appendix K.

2 Background data contained in Appendices I and J.

From an economic standpoint, changes relate chiefly to the job openings stimulated by construction. Two qualifying points must be made, though, to establish a proper perspective on a labor influx. First, the project will require about 240 men, a comparatively small number with respect to the much larger work forces assembled at the Vermont Yankee Nuclear power generating plant and the Northfield Mountain pumped storage project now under construction. Experience indicates that even if this number were to be larger than the Vernon case, it is unlikely that the supplier area would suffer any adverse effects, e.g., school over-crowding, housing shortages, transportation snarls, etc. As a second mute on impacts, it may be that workers at the Vernon nuclear and Northfield hydroelectric project will move on to the water supply project.

Apart from relatively small economic impacts, social impacts relating to supplier area residents' perceptions of equity are particularly significant. The source area feels a kind of moral outrage at being "forced to give up our water." The statements of their spokesmen sound a sense of frustration with the present system of water allocation decision-making. The personification of this attitude was observed at all of the NEWS Public Meetings held within the Connecticut River Basin. At these Public Meetings, both this report's project and a companion project at Northfield Mountain (the subject of a separate report) were subject to objections by local interests.

On the other hand, development of the Millers River Basin water supply project would insure protection from water shortages and associated social and economic losses. Estimates of economic losses prevented by project implementation when compared to project costs indicate the project to be economically efficient. With respect to the Regional Development Objective, the project would provide a benefit/cost ratio of 1.2 under average runoff conditions; and under a drought situation, this ratio was estimated to be 1.8. In the National Economic Development account, concrete losses prevented by implementation when compared to project costs yield a benefit/cost ratio of 1.2 under normal, and 1.6 under drought runoff conditions.

If the project was not implemented, social costs as well as economic costs could be expected in the receiver communities. Social impacts in the receiver area are principally "shadow costs" of concrete losses generated by water shortage. As municipal efforts turn to finding new sources, building bans to hold the line on new demand are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (especially fire protection) and a general malaise in the development plans of the subject town. In many ways, these effects are reflected in attitudes about the desirability of the town as a place to live and work. The net result is stagnating growth.

From the outset, this study made a determined effort to evaluate the impact which the Millers River Basin water supply diversion might have on Environmental Quality. An analysis was made regarding impact on the Connecticut River Estuary, on the Connecticut River downstream from the point of diversion, and on the environment of the receiving water storage reservoir.

In general, as described in the main report and fully in Appendices I and J, impact caused by the diversion on the estuary and Connecticut River itself is expected to be minimal. The primary reason for this lack of environmental impact is the relatively small amount of water when compared to river flow which would be diverted.

Possible impacts caused by implementation of the project on the Millers River would be most pronounced at the confluence of the Tully and Millers Rivers in Athol, Massachusetts. Up to 31% of the monthly flow may be diverted during an average year. However, in no case would the flow in the river be reduced below the established rate necessary to protect the river environment. Diversion would not effect ground water recharge or the ability of the river to meet water quality standards. Some lessening of the "flushing" action and a slight temperature differential may occur with diversion. On the East Branch Tully River, reduction in flows as on the Millers is expected to cause minimal effects since diversion occurs during high flows in a relatively unpolluted stream.

In evaluating environmental impact on Quabbin and Wachusett Reservoirs, field and laboratory data included about 100 parameters, including chemical, physical, biological and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information and pollution abatement plans were considered and evaluated.

Central to the evaluation was a qualitative model of reservoir dynamics. If water of lower quality such as that in the Connecticut River is introduced to a high quality supply like Quabbin Reservoir, there will most likely be a loss in the reservoir system. A number of parameters including turbidity, chemical oxygen demand, dissolved oxygen and nutrients such as nitrogen and phosphorous received close attention.

Within the receiving water body at Quabbin, the diverted flow may have impacts, but these possible impacts depend to a large degree on what engineering steps are taken prior to the actual diversion. For example, the present waste loads in the river may provide opportunities for algae growth or oxygen depletion. However, if current pollution abatement schedules are followed and the goals of the Water Quality Act of 1972 attained, then present loadings in the river will be reduced; and as a consequence, the probability of possible damage to Quabbin also minimized.

On the other hand, if no additional water is made available to the reservoir, then increased demands will reduce available storage. Declining storage volumes in turn will cause an overall loss in water quality. In addition to this possible reservoir water quality deterioration caused by reduced storage levels, supply shortages in the receiver area could also cause a loss in environmental quality for those communities served by the system.

Although exact quantifications of all potential impacts could not be defined, basically because of the present state of the art of ecological investigations, the relative probability of impacts occurring was defined. A summary of these impacts is included in the main report, and a full description of the studies is given in Appendix I - Water Quality Studies of Connecticut and Millers Rivers and Quabbin and Wachusett Reservoirs.

Followup studies of those parameters which require further detail are presently under way with sponsorship from the Metropolitan District Commission.

Finally, if the project was implemented, the additional water supplied would be returned as waste water. If this effluent was not treated adequately, it would cause a degradation of water quality in the receiver area. However, the Water Quality Act of 1972 calls for full treatment of waste discharges by the early 1980's.

E. Other Alternatives

In this report, a wide range of alternatives to the Millers River Basin Project was investigated. Included in these alternatives were other possible diversions, use of new technology as a means of augmenting existing supplies, non-structural approaches such as reduction of demand and the evaluation of the no-action alternative. A description of these alternatives and their potential as solutions to the existing problem are summarized in the following paragraphs.

1) No Action

A data baseline was first established so that changes which would occur without the proposed diversion could be measured.

In the evaluation of this alternative, it was assumed that any failure to implement additional supplies for the study area would cause socio-economic impacts on serviced communities. To verify this assumption, a quantification of these impacts was necessary.

Estimates of impacts caused by a no-action policy can be expressed in two different ways. First, concrete losses without the diversion total &96 million to 1990 and $528 million to 2020, if average runoff conditions prevailed. Under drought conditions, concrete losses without diversion total $201 million to 1990 and $623 million to 2020. Categories included in these totals encompass industrial, city emergency, city, revenue: commerce, sprinkling, business investment and domestic investment losses.

Social impacts in communities serviced by the supply system under a no-action alternative would be principally "shadow costs" of the concrete losses. As municipal efforts turn to finding other sources of supply, building bans to hold the line on new demands are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (such as fire protection) and a general malaise in the region's development plans. In many ways, these effects are reflected in attitudes about the desirability of the community as a place to live and work.

In addition to socio-economic impacts, a second major impact could occur with the no-action alternative. This second impact regards the probable deterioration in water quality within Quabbin Reservoir which could be caused by lowered reservoir volumes.

Based on the evaluation of the socio-economic and environmental impacts, the no-action alternative has many disadvantages. Use of this alternative, therefore, does not offer a realistic solution to the short range needs of the study area.

2) Weather Modification

The primary source of the water used for public and private water supply in Massachusetts, as in most humid areas, is precipitation falling directly on the areas concerned. It follows then that if precipitation can be increased in a regulated manner, the water supply can also be increased. To this end, several major agencies such as the National Oceanic and Atmospheric Administration (NOAA), the United States Bureau of Reclamation, the American Meteorological Society, and the National Science Foundation are investigating ways of productively modifying natural precipitation patterns. The primary focus of research is in the area of cloud seeding.

Research has continued to improve the state of the art of weather modification by cloud seeding and other means. At best, however, weather modification is still an inexact science. Studies are unable to predict optimum cloud conditions and seeding results with any degree of accuracy. It is the conclusion of this section, therefore, that at this time weather modification operations to augment water supplies in Massachusetts does not appear to be a viable solution to the immediate water supply problem.

3) Desalinization

Desalinization, the process in which brackish and salt water is converted to fresh, is currently being used in some parts of the world as a viable, economically feasible source of fresh water. This process thus was considered for its potential as a future alternative solution to the water supply needs of eastern Massachusetts.

The conversion of saline to fresh water is accomplished through four major processes: distillation - evaporation, membrane separation, crystallization, and chemical differentiation.

Desalinization by numerous processes is already feasible in parts of the world when the natural water supply is either scarce or of poor quality. In these areas, the relatively high costs of water produced by desalinization are justified. Research completed by the Office of Saline Water has indicated that when larger capacity plants are designed and in production, the costs could ultimately be reduced to approximately 50¢ per thousand gallons in the size range of the Millers River Basin Project, although a recently proposed California plant would produce water at 73¢ per thousand gallons. Even at this reduced cost, however, desalinization is not competitive with present costs of developing natural surface and sub-surface water supplies. For example, costs of water from this report's recommended project is about 15¢ per thousand gallons.

Aside from the economic costs involved with desalinization, the Office of Saline Water is also investigating the potential hazards to the environment. In considering placement for any type of desalting plant, environmental factors are as important as any other factor. Pure water is not the only product. A plant will produce extremely concentrated brine as an effluent, plus any waste products from the power source such as soot, heat, smoke, toxic gasses, etc. So far as brine is concerned, this brine from distillation plants is of high temperature, higher chloride content and may contain concentrations of copper which may prove injurious to the environment. Two methods of brine disposal have been studied: (1) evaporation to dryness; and (2) deep-well injection. Evaporation is expensive, though this is highly dependent on land costs presently quite costly in urban areas such as this report's study area. Injection method costs are estimated at 25 to 70 cents per 1,000 gallons of brine. Such costs must be added to plant production and distribution costs to arrive at a true cost of water from this technology. At present, the Office of Saline Water is investigating other methods of brine disposal.

On the basis of the economic costs and environmental problems associated with this technology, this report concludes that desalinization not be considered at this time as a viable alternative source of water in eastern Massachusetts for the short range water supply problems. When and if the technology and efficiency of this process is refined so that it is economically and environmentally competitive with other methods of supplying water, its feasibility can be reevaluated.

4) Importation

During the crisis years of the sixties' drought, many newspaper and periodical articles pondered the possibility of diverting water from extra-regional sources as a solution. One of the major basins often mentioned as a water supply source for the Northeast was the St. Lawrence. As an alternative to developing local resources to meet future water needs, an investigation was made regarding the feasibility of diverting St. Lawrence flow to meet future needs.

Engineering studies were conducted to assess various methods and quantities of development from the basin. Cost estimates were prepared for projects which would service all of the Northeast through the year 2020. Construction costs for such facilities were estimated to be as high as 8.5 billion dollars, excluding any necessary water treatment costs. Water delivered from such an undertaking would cost substantially more than similar volumes made available from local resource potential; however, it would service a much larger region and in this context may have future potential.

In addition to the high cost of water, this alternative also has several other major disadvantages. First, the nature of the project would not allow stage development. Thus, large expenditures of funds would be required for distant long range needs. Second, since the basin is international, negotiations with Canada would have to be held and a treaty consummated prior to diversion. Assuming that Canada would be favorable to such negotiations, at best, any treaty would be in the distant future.

Based on the results of investigations conducted as part of this report, the importing of water to meet short range water supply needs does not present a viable alternative for the Southeastern New England Region's immediate problems.

5) Direct Waste Water Reuse As A Municipal Supply

Waste water reuse, especially in industrial process application, has been economically successful in many sections of the country.

Other uses to which treated waste water has been applied include irrigation of both crop land and lawns, as a fresh water barrier against salt water intrusion, and in some cases as a source of supply for formation of recreation lakes and ponds.

Direct reuse of waste water effluent as a public water supply, however, has not been utilized to a large degree. Advanced waste treatment research and development programs at the Federal level are continuing, and pilot plant studies such as the noted Lake Tahoe project are apparently meeting with some success in producing a high quality effluent.

The current Drinking Water Standards do not apply to direct reuse of reclaimed water for drinking. Health officials feel many questions remain unanswered which must be fully investigated if renovated waste water is to be considered for drinking water purposes. Research is considered vital before development of intimate personal-contact uses of renovated waste waters.

The future of direct waste water reuse particularly in industrial applications seems promising. Future water demand forecasts for industrial usage used in this report, in fact, anticipate greater recycling of water in the industrial sector.

Use of renovated waste water as a regular domestic supply, however, requires full results of proposed research. Until such research is completed, waste water reuse as a municipal water supply is not a viable alternative to meet short range supply needs.

6) Ground Water Resources

A study[1] of the ground water resources of Massachusetts was prepared for the Corps of Engineers by the United States Geological Survey. The study was based upon analysis and interpretation of available data and did not include any new exploratory work. The objectives of the study included an estimate of the area extent and sustained yield of principal aquifer reservoirs which might be used for supplementing municipal and industrial water supplies.

The survey of ground water resources indicated that the aquifers in Plymouth County and parts of Cape Cod have the capacity to sustain long term, large magnitude withdrawals. The water demand on Cape Cod is increasing at a fast rate; therefore, this area is not considered in this report. The Plymouth County area studied comprises 300 square miles and its estimated safe yield is 300 mgd. This estimated rate exceeds the required quantity established as a goal of this study. Thus, it was concluded that the Plymouth County area could offer a viable alternative source of water supply for eastern Massachusetts.

Cost estimates for the necessary resource development were then prepared. Major development items included in these estimates were land acquisition, cost of ground water well development, water treatment facilities, pumping installations and connecting aqueduct system to the metropolitan service area. The estimated construction cost for the ground water development per million gallons per day (mgd) capacity is about 1.4 million dollars. Costs for the Millers River Basin project, on the other hand, are estimated to be about $550,000 per mgd capacity. Annual costs of ground water development which includes interest and amortization; maintenance, repair and operating cost; and major replacement costs are estimated to require

[1] This investigation was conducted as part of the feasibility study for potential engineering alternatives in the study area.

charges of about 30¢ per 1000 gallons produced. Annual costs for the Millers River Basin Project would require about 15¢ per 1000 gallons produced.

In addition to the economic costs associated with development of the ground water alternative, there are also potentially significant environmental and socio-economic impacts. For example, land taking activities associated with sanitary protection of the various wells may be substantial. Preliminary estimates of necessary land acquisition for the wellfield development indicate 1,000 to 1,500 acres of land would be necessary. This compares quite unfavorably with the 40 acres estimated to be required for the Millers River Basin water supply project.

Connecting pipelines between wells in the wellfield and transmission facilities to point of use would require a large amount of surface construction. Such extensive surface construction would have an impact on the environment in the vicinity of the wellfield and transmission facilities. Since portions of the aqueduct systems would pass through heavily urbanized areas, disruption would be expected to be extensive.

Since all water developed from the wellfield would have to be pumped to the consumer, this alternative would utilize large amounts of electricity. Thus, depending on the method used to provide this power, impacts on the environment can be expected.

The Millers River Basin Project would not utilize pumps; therefore, no additional potential environmental damage would accrue because of power requirements.

On the basis, then, of cost comparisons and potential socio-economic impacts, use of ground water does not appear to offer an attractive alternative to the proposed project.

7) Dual Water Supply Systems

An alternative which has been receiving attention of late has been the use of dual water supply systems. In these systems, a hierarchy of water supply would be established whereby higher quality supplies could be used to furnish a potable source for drinking, cooking, dishwashing, cleaning, bathing and laundering. All other uses could be furnished by a second supply of lesser quality.

Two general methods have been suggested for such a dual system. The first is the possibility of recycling at the point of usage. Under this scheme, drinking, washing and bathing water would undergo treatment and then be further utilized as toilet flush water and outdoor uses. It is estimated that such a system could reduce domestic water use by as much as 50%.

Various systems for in-house reuse or for outdoor usage have been proposed, and some are being marketed on a small scale.

Advantages to this system beyond potable water consumption reduction are the reduction in sewage water volume, sewer pipe and pumping requirements. Capital cost outlay for such a system based on limited cost data would be over twice as expensive as water delivered from this report's recommended project. Other disadvantages to this alternative lie with its limited application and accompanying operational experience, potential problems of odor and other aesthetic considerations. Health officials in general have not expressed their acceptance or rejection of such systems. However, their general apprehension on introducing less than potable water into the home environment could also reasonably be expected with regard to any system of this nature.

The second method which has been suggested for delivering higher and lower quality water for various uses would require a second distribution system. This second distribution system would carry river water or even sea water to supplement the high quality primary supply source.

To estimate costs for such a system, a report on the New York City area, prepared as part of the NEWS Study, was utilized. Based on the results of that investigation, preliminary capital cost estimates for such a dual system would be about 6.5 million dollars per mgd saved. The Millers River Basin Project recommended in this report is estimated to cost about $550,000 per mgd. Therefore, use of a dual supply distribution system as an alternative would be an extremely expensive alternative.

In summary, then, use of dual water supply systems to meet immediate short range supply needs does not offer an alternative to the recommended project in this report. Of the two methods, the system which would recycle water at the point of usage holds the more promise for future application.

8) <u>Other Diversion Sites</u>

In addition to the Millers River Basin Diversion proposals described in this report, a number of other diversion possibilities were also evaluated. These other possible sources included diversions from: the mainstem Connecticut River at a number of locations; the Deerfield River, a major tributary of the Connecticut River; the mainstem of the Merrimack River and the Sudbury River, a tributary of the Merrimack, formerly extensively used by the MDC.

The possibility of diversions from the Connecticut River at Northfield Mountain offers a viable companion source which when combined with the yield of the Millers River Basin would allow serviced communities to meet short range needs. Development of this Northfield Mountain potential is the subject of another Interim Report of Survey.

Other alternative development of the Connecticut River Basin to meet short range needs such as the Deerfield River or another location on the Connecticut River itself could provide an equivalent yield to that of Millers River Basin Project. Development of either of these proposals, however, would be more expensive than the Northfield Mountain Project of the Millers River Basin Project. Aside from economic costs, neither alternative presents any clear cut advantage from an environmental or socio-economic viewpoint.

As an alternative to further diversions from the Connecticut River Basin, the potential of developing the mainstem Merrimack River was also investigated. At present, the physical, chemical and bacteriological quality of the river is poor. For years, the river has been subjected to major discharges of municipal wastes.

An investigation in feasibility detail[1] was conducted to assess methods of improving water quality within the river. At present, an Interim Report of Survey by the NEWS Study is evaluating alternative waste treatment techniques which would improve the river's quality. As a companion study to the waste water element, investigations in survey detail on the river's potential for water supply development are also being conducted.

Based on studies to date, use of the river to meet longer term supply needs holds promise. Use of the river to meet immediate needs within the study area, however, does not appear to offer an attractive alternative to this report's recommended project from either an economic or public health standpoint.

One of the earlier historical supply sources of the MDC was development on a portion of the Sudbury River Basin, a tributary of the Merrimack River. In 1947, in response to the availability of supply from Quabbin Reservoir and the higher quality water from this source, the Massachusetts Legislature transferred control of a number of supply reservoirs to the Department of Conservation.

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[1] The Merrimack: Designs for a Clean River: Alternatives for Managing Wastewater in the Merrimack River Basin, September 1971, prepared for the Northeastern United States Water Supply Study.

With its existing available supplies, the MDC is presently re-evaluating the potential which the full Sudbury system may have. The Sudbury Basin waters, however, have a number of reported water quality problems, thus water treatment facilities would be necessary to develop this source. Based on preliminary cost figures, this redevelopment could cost about twice that of this report's recommended project.

In summary, then, the redevelopment of the Sudbury River Basin could add an attractive increment to the region's available supplies. The redevelopment plan needs further study for a full assessment of its potential; and if implemented, it would be fully compatible with this report's recommended project.

9) Water Demand Control

The NEWS Study, cognizant of the margin separating available yield and consumer demand, conducted studies on methods available to alleviate this critical water supply situation. Two general approaches to the problem were investigated: the first considered various methods of increasing the supply available to the system; the second approach summarized in this section, and recognizing the possible long term implication of conservation measures, was investigation of methods whereby demand could be curtailed.

There are basically five methods which have been suggested as effective in controlling demands on water supplies. These are:

(1) Changing from flat-rate to metered supply
(2) Increasing the price of metered supply
(3) Imposing of restrictions on water use
(4) Utilization of water-saving devices
(5) Public Water Conservation Education Programs

Each of these methods, outlined above, are described in the following sections as they might apply to the demand forecasts prepared for this report.

(1) Metering

The installation of meters which measure the amount of water used by a consumer have been shown to be effective in varying degrees in reducing demand for water supply. With metering, the customer is now charged for the quantity of water used, instead of being charged a flat rate for a period of time regardless of quantity used. Most of the studies conducted regarding the effects of metering indicate domestic in-house use is relatively in-elastic, but lawn sprinkling use and some industrial applications apparently are affected.

Use of metering then appears to present a good opportunity for conservation of a resource. In the Boston area, however, application of this technique to reduce demand is quite limited. Most municipalities in eastern Massachusetts already meter extensively. For example, the customers of communities served by the MDC are presently 96 percent metered. Complete metering, therefore, would affect only 4 percent of service connections in this system and not, therefore, affect to any significance, water supply demands forecast in this study.

(2) Pricing Effects on a Metered Supply

A number of articles have appeared in recent years in water supply and water resource professional journals regarding the impact of price increases on water demand. All of these articles attempt to quantify the constraining influence which pricing may have upon demands. In these articles, a number of various pricing techniques have been suggested for administration of price hikes. These include general increases in price levels, seasonal pricing and increasing block rates for varying usage of water. Aside from the administrative technique employed, however, the objective of the articles is to define impact of price increases on demand. Generally, the authors, however, are forced to base conclusions on a generally incomplete and sporadic empirical data base.

On the basis of equations submitted by some of these authors, price adjustments would appear to offer an alternative to development of supplemental water supplies. Theoretically, a price increase of 50¢ per 1,000 gallons could be expected to reduce domestic in-house demands by about 34 mgd and a corresponding decrease in lawn sprinkling demand by about 5 mgd. Industrial water use demands are indicated to react by decreasing almost 14 mgd. The total theoretical decrease on the system then with such a price increase would be about 53 mgd.

On the basis of the theoretical equations then pricing would appear to be a valuable tool for conservation of the water resource. A number of questions, however, arise concerning the direct application of these forecast decreased demands to the water supply situation at hand.

First, the empirical data used in the derivation of the domestic use equations, although the most extensive to date, is far from all inclusive. Data used was derived from 21 areas nationwide, which contained about 5000 dwelling units. None of the test areas were located within southeastern New England, although data available from the Middle Atlantic States was used.

In the analysis of industrial water demand reaction, data utilized was quite limited, and other research in this area is almost non-existent. Development of any hard policy conclusions based on such sketchy information is, therefore, uncertain at best.

Second, the derivation of the empirical equations for domestic use was based on a "static" view of cost versus use. That is, the data employed was not an observation of a group of communities' actual reaction to pricing changes. Rather, the equations were developed by using a number of communities, which for a given point in time, had different water use with their individual rate structures. For example, Community A in 1970 used 100 gpcd at a cost of 20¢ per thousand gallons; Community B in the same year recorded an average use of 50 gpcd at a cost of 40¢ per thousand gallons. Based on the approach used by Howe and Linaweaver, the expected decrease in use from Community A with a price increase to 40¢/1000 gallons would be 50 gpcd. Whether the use of such a "static" scenerio to predict dynamic conditions is valid is unknown.

That the equations may not indeed reflect the dynamic situation which would occur with a price increase is particularly suspect with actual operating experience in the Boston Region. For example, in the Boston Region, the MDC increased wholesale prices for its water from $40 to $80 per million gallons in 1954, and $80 to the current $120 per million gallons in 1962. Neither of these price increases was accompanied by a decrease in per capita demand on the system; in fact, demand increased on the system.

To further evaluate the dynamic impact of pricing in an actual operating experience, a survey was made of a privately owned water company which recently applied a 24¢ per 1000 gallons to its water rates. This rate increase raised the cost of water to the consumer from $1.00 to $1.24 per 1000 gallons. The two communities serviced by the company are principally residential, thus the rate increase based on the empirical equation should be expected to result in a demand decrease, or in any event, a decrease in the rate of increase. The company reports, however, that instead of experiencing a decrease in per capita usage, it experienced a 5 gpcd increase, an increase in excess of that reported in years prior to the price increase.

Based on the actual operating experience of these utilities within Metropolitan Boston, it appears any arbitrary adoption of the empirical equation as a forecast tool with respect to water demand carries a large degree of uncertainty.

Third, all of the studies upon which the pricing-demand relationship was developed have been basically economic studies. No attempts have been made to evaluate or quantify cost to the consumers from either environmental quality or social considerations. Both the social and environmental costs of reducing water demand may outweigh the gains derived from institution of such a policy. Whether, in fact, the costs would outweigh the benefits is unfortunately unknown.

In summary, use of increased water supply prices as a method to conserve a resource may have merit. Yet to be determined, however, are data to support the theoretical impact such increases would have upon the demand within New England. Also unknown with this approach are the social and environmental costs which would be borne by the consumer. It appears then that much work remains to be done on this approach such that it can be evaluated as a viable alternative to increased supply.

(3) *Imposing of Restrictions on Water Use*

Historically, water utilities have used water use restrictions as a "safety factor" against depletion of supply during a drought. In general, however, most water utilities attempt to avoid restrictions whenever practical. Public reaction to such restrictions, however, is almost always unfavorable, and many examples of such public disapproval can be found in newspaper clippings during the recent sixties' drought.

Imposition of restrictions on water use could not fail to interrupt the existing and planned life styles of communities serviced by a water supply system. As described in the appendix on socio-economic impacts, restrictions on water use, depending on its degree, would have far reaching social and economic costs. On the basis of costs which would be incurred with a restriction policy, it does not appear to offer a viable alternative.

(4) Utilization of Water Saving Devices In-House

Much of the recent increase in municipal water supply by individual consumers has been attributed to the adoption of multiple toilet facilities; water using devices such as automatic clothes and dish washers; and shower installations. Variation in water use between brand names differs markedly. For example, automatic home washers for an 8 pound load require from 32 to 59 gallons per load, while toilets vary from 3.2 to 8 gallons per usage. Information on the impact of domestic water saving appliances on in-house use is limited and variable in quality.

An article[1] presented last year in the American Water Works Association demonstrated possible water savings which could be brought about by adoption of presently available appliances for toilet, clothes washing and shower use. Based on their findings, the authors conclude that there doesn't appear to be current financial incentives for adoption of water saving appliances. They do note, however, that conversely economic costs to consumers from utilizing water saving appliances do not seem great. Presumably, their conclusion refers to replacement costs when currently used appliances wear out. The authors suggest that complete replacement of appliances with water saving models might reduce domestic water use by 32 percent.

A second study[2] of water conservation measures for the Office of Water Resources, U. S. Department of the Interior, also contains some information on water saving devices. In this study, it was noted that increasing use of water by automatic dish and clothes washers over the years has been occasioned by a rise in required performance standards. Thus, customer desires are reflected in the increased water use.

A third study[3] recently completed for the Washington Suburban Sanitary Commission provides a brief review on the effectiveness of water saving measures and the relationship of their use to rate-making policy

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[1] Howe, Charles W. and Vaugham, William J. "In House Water Savings," Journal of the American Water Works Association, Vol. 64, No. 2, (February 1972).

[2] Hittman Associates, Inc., "Main C. Computerized Methodology for Evaluation of Municipal Water Conservation Research Programs," No. HIT-409, Columbia, Maryland, August 1969.

[3] Boland, John J., Hanke, Steve H., and Church, Richard L. An Assessment of Rate-Making Policy Alternatives for the Washington Suburban Sanitary Commission, Prepared for the Washington Suburban Sanitary Commission, September 1972.

formulation. In this report, the authors state "A major deficiency in the data reported by all investigators to date is that it refers to isolated uses of specific appliances and fixtures, but does not reflect actual use conditions."

In reference to the suggestion that 32 percent of the domestic water use could be saved by adoption of water saving devices, the authors state "Such a result implies, of course, no reduction in the actual or perceived efficiency of operation of any of the appliances or futures. In the latter instance, the net reduction in water use is more difficult to predict; however, it should be somewhat less than 32 percent."

Statements made at a number of progress meetings suggested that use of incentives such as subsidies or tax concessions and revision of plumbing codes to require water saving devices would result in substantial water savings. In general, however, the same questions which burden analysis of price as a demand moderation measure also apply to use of water saving devices. Regardless of managerial technique used to implement use of such devices (i. e., subsidy, tax concessions, etc.) the question still remains as to the effectiveness and impacts on water use which may occur. Research conducted to date has been limited. In addition, socio-economic impacts which might occur with a general requirement that older appliances be replaced with the water saving models has not been addressed at all. Environmental impacts generated as a spinoff of producing the new replacement models may also be significant and must be included in any analysis.

In summary, adoption of water saving devices as a method of conserving water supply may have merit in the long run. At present, however, supporting data to measure the impacts of either requiring new housing units or replacement by older housing with water saving appliances is not available. Without this data, evaluation of potential savings as an alternative course of action to the recommended project cannot be documented.

(5) Public Water Conservation Education Programs

Historically, the water supply industry has not advocated wide-scale public water conservation, except in communities where supply or distribution systems were inadequate to meet demand. Recently, however, increased awareness of the need to protect and enhance the environment has required a review of this earlier policy.

At present, two major metropolitan supply systems[1] have adopted a water conservation policy during a time of water surplus. In the past year, both utilities have promoted expanded voluntary customer water conservation through a public education program.

Bill inserts and information handbooks on water-saving measures have been distributed widely. In addition, speeches to individuals, schools and clubs have been employed to inform the public of why the water resource should be used properly and what they can do to help conserve water. Results of the education programs are now being evaluated for their effectiveness.

The Washington utility which has the longest experience record reports results have been encouraging to date; however, major reductions in per capita usage have not been observed.

In addition to voluntary conservation measures, the two utilities are also considering the use of regulatory powers to conserve water. Regulatory measures under consideration include, for example, price increases, utilization of water-saving household appliances and restriction of lawn sizes. All such measures, however, are being carefully evaluated by the utilities because of the many questions, described in earlier sections, which surround use of such devices.

In summary, adoption of public water conservation programs as a management tool has received attention of late. Results on water use modification of the voluntary conservation programs now under way are limited. However, based on the Washington area experience, no major decrease in per capita usage has been observed.

10) <u>Re-Examination of the Swift and Ware Rivers Downstream Release Schedules</u>

At the time diversions were contemplated from the Connecticut River Basin, via the Swift and Ware Rivers, Massachusetts applied to the Secretary of War for authority to make the proposed diversions. After hearing arguments pro and con from Massachusetts and Connecticut, the Secretary permitted diversion of the flood waters of the Ware in excess of 85 million gallons per day between 15 October and 15 June and prohibited the taking of any water except during that period.

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[1] Washington Suburban Sanitary Commission and East Bay Municipal Utility District. Note: both utilities service populations of about 1.1 million each.

With regard to the Swift River, the Secretary permitted diversion of all waters of the Swift except enough to maintain a flow therein of 20 million gallons per day (mgd) or 31 cubic feet per second (cfs). The Secretary did require that during the period from 1 June to 30 November, there shall be released from the impounding dam 71 mgd (110 cfs) whenever the flow of the Connecticut River at Sunderland, Massachusetts is 4650 cfs and 45 mgd (70 cfs); when the flow is more than 4,650 and less than 4,900 cfs.

These findings of the Secretary of War regarding operational schedules for the diversions were later made a part of the Supreme Court Decision, dated March 1931, in the suit between Connecticut and Massachusetts. Since the date of that decision, diversions from the Swift and Ware Rivers have been accomplished under the Secretary of War findings.

During the progress of the NEWS Study, an interested citizens' group suggested the setting aside of the Swift River diversion limitations with the objective of retaining presently scheduled releases within Quabbin Reservoir. The citizen group further suggested any diminution of flow in the Connecticut River could be made up by releases from existing Corps of Engineers' flood control reservoirs. In keeping with this suggestion, an examination was made of the potential which such rescheduling might have on the short-range supply problems.

The drainage area of the Swift River controlled by the Quabbin Reservoir totals 186 square miles. The long-term average annual runoff from the watershed is 187 mgd (289 cfs) of which 32 mgd (50 cfs) has been released downstream in compliance with the existing downstream release schedule.

Thus, the maximum addition to the existing water supply system which could be achieved through re-scheduling would be 32 mgd (50 cfs). To provide this increment, however, all downstream releases with the subsequent "drying up" of the river reach downstream are, of course, impracticable. The question then raised is what level is practicable. A recent study[1] completed for the entire Connecticut River Basin recommends an instantaneous discharge rate, from power reservoirs on the Connecticut River of 0.20 cubic feet per second per square mile of upstream watershed. An application of this criteria to Quabbin

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[1] Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin, Connecticut River Basin Coordinating Committee, June 1970.

Reservoir, for example, would result in a downstream release requirement of 24 mgd (37 cfs). Adoption, then, of such a modified operational schedule could result in an additional 8 mgd being made available. This increment of yield, however, would not begin to meet the short-range needs of this report's study area which are estimated to total an additional 141 mgd. In short, then, a re-examination of downstream release schedules with the objective of conserving such releases for water supply has merit. However, based on the requirement of maintaining a viable river environment downstream from Quabbin, the opportunity for reducing downstream releases does not offer an alternative to the project reported upon in this study.

The spring runoff which occurred in 1972 was of longer duration and of greater magnitude than is usually experienced. As a result, diversions from the Ware River, in compliance with the operation schedule, described earlier, were forced to cease even though flows in excess of 85 mgd were still occurring. This event triggered a suggestion to the NEWS Study that if the 15 June to 15 October no diversion constraint were lifted, large additional supplies of water could be made available to Quabbin.

A computer test was made to determine the impact of the 15 June to 15 October constraint. The results of the computer simulation indicated that only an additional 2.6 mgd might be made available if the 4 month no diversion period currently in effect was terminated.

In the Ware River, as in the case of the Swift River, a re-examination of downstream release schedules may have merit. However, terminating the 15 June to 15 October diversion period constraint does not offer an alternative to this report's recommended project.

F. Coordination

Since the initiation of this work, a determined effort has been made to inform the public of the work's progress. Nine progress meetings were held in the Boston Metropolitan area, generally at Waltham, Massachusetts; the first held on 7 May 1970, with the latest held on 7 June 1972. Attendance at these meetings generally averaged about 50 people, with attendees representing Federal and State Agencies, conservation commissions, the Audubon Society, sportsmen groups, and interested citizens.

In addition to the progress meetings, four informal information meetings have been held within the Millers River Basin. These meetings were held in Athol, Massachusetts on 21 October 1971 and 4 January

1972; in Winchendon, Massachusetts on 2 March 1972; and in Athol, Massachusetts on 8 May 1972.

During December 1971 and January 1972, a series of four formulation stage public meetings were held in Needham, Woburn, Orange and Longmeadow, Massachusetts. These meetings were designed to broaden public participation in the open planning process by describing the on-going studies and receiving audience input.

In July 1972, two late stage public meetings were held at Waltham and Orange, Massachusetts, and the various plans for augmenting water supply systems were discussed and described.

A full description of the coordination held during the study is included in the main report and Appendix M.

4. Conclusions

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population. The sixties' drought which began in 1961 ultimately through its duration directly affected the water use patterns of more than 20 million people. In 1965 alone, drought-related water shortages and associated problems were severe enough to warrant emergency actions by local, State and Federal agencies. Within Massachusetts, for example, more than 50 cities and towns imposed restrictions on water use.

During and following the drought, a number of communities and regional planning agencies conducted engineering studies to determine methods for augmenting existing supplies. In many cases, new supplies have been developed by communities which would allow them to meet future needs. Investigations conducted by the NEWS Study in Southeastern New England indicate that even with the actions undertaken by local authorities, additional supplies must be made available if future needs are to be met.

In 1969, a feasibility report on possible engineering alternatives to meet the region's needs was prepared by the NEWS Study. A total of 28 projects were identified as possible candidates for implementation to provide an adequate water supply system within the region. The Millers River Basin project examined in this report was one of the engineering alternatives included in the feasibility study. Upon implementation, output from the project would provide additional supply, as shown on Plate No. S-4, to meet a large segment of the region's future needs.

This report has investigated and assessed all aspects of the water supply situation within the study area. The Metropolitan District Commission (MDC), Boston, is the largest regional system in New England, supplying about two million people in 1970. The MDC relies upon surface water as its supply source, and the present estimated safe yield of these sources is 300 million gallons per day (mgd). In 1971, the average daily delivery of water from this system was about 322 mgd. Available safe yield of the largest regional system in New England has been outstripped by rising supply demands.

The land area encompassed by this study falls within the boundaries of the so-called "megalopolis" which extends from Boston, Massachusetts to Washington, D. C. Latest population estimates for the Massachusetts study area forecast increases from 5.5 million in 1970 to 6.7 million by 1990, and 8.4 million by the year 2020.

Estimates of future water requirements within the region and on the existing regional system demonstrate the need for additional supply. Development of a single regional system to meet 1990 needs of all communities within the study area was not found to be an attractive approach, either from an economic or resource utilization viewpoint.

Based on a review of the area's present and projected water supply needs, it is concluded that the MDC system, as it exists at present, will require additional supply. In addition, studies reveal about 23 communities which may require admission to the system to satisfy their short range (1990) needs.

The estimated total demand for 1990 for presently serviced and other needy communities on the existing regional (MDC) supply sources is calculated to be about 441 mgd. Future demand forecasts were derived using both population and industrial output projections. In general, although some modification of consumer and industrial water usage patterns are included in these estimates, no major modifications or shifts in usage patterns are included.

In order to meet the 141 mgd additional demand, a large number of alternatives were investigated to determine their environmental and socio-economic impacts. Alternatives to the Millers River Basin project included no action, desalination, groundwater development, waste water reuse, other diversion sites, re-regulation of existing supply sources, local resource development and controlling the water supply demand. Based on the investigations conducted, it is concluded that the Millers River Basin supply project offers an attractive opportunity for providing early relief to the short range needs.

In the evaluation of the Millers Basin Project, particular attention was given to the impacts on downstream water users which implementation might cause. All of the investigations indicated minimal downstream effects could be expected with operation of the project.

On the other hand, implementation of the project would provide protection against water shortages and associated socio-economic losses. Estimates of economic losses prevented when compared to project costs demonstrate the economic efficiency of the project. With respect to the Regional Development objective, the project would provide a benefit/cost ratio of 1.2 under average runoff conditions; and under a drought situation, the ratio was estimated to be 1.8. In the National Economic Development account, the benefit/cost is estimated to be 1.1 under normal and 1.6 under drought runoff conditions.

In assessing the Environmental Quality Impact, the Connecticut River Estuary, the river itself and the receiving water body at Quabbin Reservoir were examined to determine what change would accompany the project's implementation. In general, minimal changes can be expected in the river and estuary downstream of the diversion intake. These minimal impacts forecast are due to the relatively small diversion volumes compared with river flow. Within Quabbin Reservoir, it is expected that the diverted flow would have limited impacts and would prevent serious drawdowns of reservoir storage. This conclusion is based on the existing water quality of the Tully River and anticipated quality of the Millers River after clean-up. Impacts on the Millers and Tully Rivers downstream from the project's intakes could be larger than those on the Connecticut. This conclusion is based on the relative amounts of water which would be diverted from these tributaries. Major impacts, however, are not predicted.

Based on all investigations conducted, it is concluded that resources are available within the region which can be developed from both economical and environmental viewpoints. Development of these resources through the Millers River Basin Project and a companion project (subject of another report) offers a means of meeting supply needs through 1990. The availability of the resource and the opportunity for their development provides an optimistic outlook for the region at least in the short run.

In addition to the conclusion that the Millers River Basin Project should be implemented, it is also felt that concurrent investigations on water demand and its makeup should be conducted.

For example, detailed breakdown of water use or demand by consumers is not readily available. Although use, on a per capita basis, is readily available, data on how and by whom the water is used is not well documented. Increased per capita demands are, of course, a reflection of the nation's rising standard of living, but the breakdown of this demand into various use categories is poorly understood. A clearer understanding of the breakdown would permit the most efficient long range use of water supply resources.

Household items, which are undoubtedly contributing to increased water usage, include clothes and dish washing machines; multiple toilet facilities, and installation of shower facilities. Among these appliances, a wide range of water requirements per usage is needed. A search of available literature indicates these wide variances in water requirements may not be occasioned by economic or environmental efficiency objectives, but rather the result of independent design criteria. It appears then a rationalization of criteria used in design of water using appliances may offer opportunities for reduction of longer range water needs upon the public supply systems. The true measure of this opportunity would require extensive investigation, including the various appliances' efficient water needs; the impact which re-design would have on consumers; identification of incentives necessary to achieve full use of such devices, such as use of plumbing regulations, subsidies, and the effect which such potential in-house savings may have on future, particularly long range, water demands.

A second area worthy of investigation regards the impact which restructuring of pricing policy as a conservation measure for long range needs may have. Studies conducted to date indicate increases in cost of water supplied to the consumer may decrease use of water by the individual. Data developed to date on this pricing/use reaction has been limited. Thus, any theoretical anticipated decrease in water use caused by a price hike must be viewed as speculative.

In addition, none of the work has addressed the question of whether such price increases would in fact be beneficial or detrimental to the socio-economic objectives of the public water supply consumer. For example, if water rates were raised substantially in excess of the economic costs of delivering the water, the rate increase would, in effect, be a tax placed upon the consumer; consequently, questions of equity then arise. In short, the use of pricing as a conservation tool is an unproven venture, given the present "state of the art" concerning its potential benefits and possible shortcomings. Studies should be conducted, therefore, which address these questions and provide answers as to the impacts of such measures.

During the course of the study, at a number of informal progress and formal public meetings, it became evident that public interest in water supply planning was far from consistent. Meetings held within the Connecticut River Basin or the supplier area always were well attended with high audience participation. On the other hand, at three public meetings held in the Eastern Massachusetts region, the area which could be supplied water from this report's recommended project, less than 50 people attended each of the meetings. It appears that the public in Eastern Massachusetts takes its present good quality and available water as unlimited. This attitude can be attributed, in part at least, to the continuing availability of supply made available by the efforts of the local and regional water supply agencies. The question arises, however, whether such casual public concern over their water resources is a healthy state of mind. Many conservation groups at the NEWS meetings characterized this lack of public concern as leading to misuse of the resources through waste. There is no evidence to substantiate this charge in the study region. However, an education program to inform the public about their supply system, its limits and future, is in consonance with good management practice. The development of such an educational program, therefore, not only within the study area of this report, but nation-wide, should be considered as part of any water supply plan.

Throughout the conduct of this study, a number of groups, primarily conservation oriented, have advocated the re-cycling of waste water for water supply uses. In some cases, such as in certain industrial processes, effluent from waste treatment facilities can be utilized. The direct use of such waste water effluent, regardless of the degree of waste water treatment, as a source of supply for municipal systems is not recommended at this time. Echoing the position of the Division of Water Supply, Environmental Protection Agency, State and local health officials and professional water supply engineers, any application of reused water as a municipal supply would require a considerable amount of research on associated potential health hazards. Since, in many regions, less than desirable sources may be needed in the future, it is imperative that such research be accelerated.

The Millers River Basin Water Supply Project would be an important supply increment in the regional plan for the metropolitan Boston area and is compatible with the short and long range water resource development objectives of the region. Included in the regional plan for the Boston area would be the Northfield Mountain Project described in a companion report. Also, there is the possibility of utilizing the South Sudbury River and/or the Merrimack River for future demands. Studies should be conducted to determine whether certain measures designed to conserve and moderate water demand should be implemented to reduce the size of needed long range water supply developments. For the region as a whole, water resources are available which can be developed efficiently from both an environmental and economic viewpoint to meet the water demands. Sources include the Merrimack, Taunton, North and Connecticut River Basins, together with local groundwater sources. The future water supply view of the area, therefore, can be described as optimistic. However, a continuing planning program, dynamic in nature, must be pursued to insure adequate, safe, dependable water supplies are available when necessary.

MILLERS RIVER BASIN WATER SUPPLY PROJECT

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SECTION VIII - ESTIMATES OF FIRST COSTS AND ANNUAL CHARGES

TABLES

PLATES

MILLERS RIVER BASIN WATER SUPPLY PROJECT

SECTION I

GENERAL

1. Purpose

The severe five-year sixties' drought which plagued the Northeastern United States revealed a soon to be critical water shortage within eastern Massachusetts. More important detailed examination accomplished in this study indicates that many water supplies available to this area are inadequate to meet today's needs and the area's expanding population and industrial growth. This report presents a plan for diverting excess high flows from the Millers River Basin, a major tributary of the Connecticut River, to meet a portion of the future water supply needs within eastern Massachusetts. The study area is shown on Plate No. 1.

2. Authority

The Northeastern United States Water Supply Study (NEWS) was authorized by Congress under Title I of Public Law 89-298, enacted on 27 October 1965. Congress thereby recognized that assuring adequate water supplied for our great metropolitan centers had become a problem requiring the assistance of the Federal Government in its resolution.

Under direction of the Congress, the Secretary of the Army, acting through the Chief of Engineers, was authorized to cooperate with Federal, State and local agencies in preparing plans in accordance with the Water Resources Planning Act, Public Law 89-80, to meet the long-range water needs of the Northeastern United States. In meeting these needs, this plan may provide for the construction, operation and maintenance by the United States of a system of major reservoirs, major conveyance facilities and major purification facilities within the study area. The Chief of Engineers in turn assigned responsibility for the NEWS Study to the Division Engineer, North Atlantic. This report is submitted in partial fulfillment of the above authorization and will be incorporated as part of the overall NEWS effort. A plan of the entire NEWS study area is shown on Plate No. 2.

3. Scope of Studies

Studies conducted as part of this report included the following tasks:

a) Detailed projections of population, water demand, and potential service areas, principally within Eastern Massachusetts as well as within the Connecticut River Basin, were completed in this study.

b) Geologic investigations with existing sub-surface data of proposed tunnel and conduit routes and reservoir sites were accomplished.

c) Requirements for waste and water treatment studies were investigated.

d) Ecological and environmental studies were completed which consider the effects, both immediate and future, of the various proposals on the environment and ecology of both the Connecticut River, its estuary, and the receiving storage impoundment at Quabbin Reservoir.

e) Hydrologic and hydraulic analyses.

f) Economic studies and evaluations.

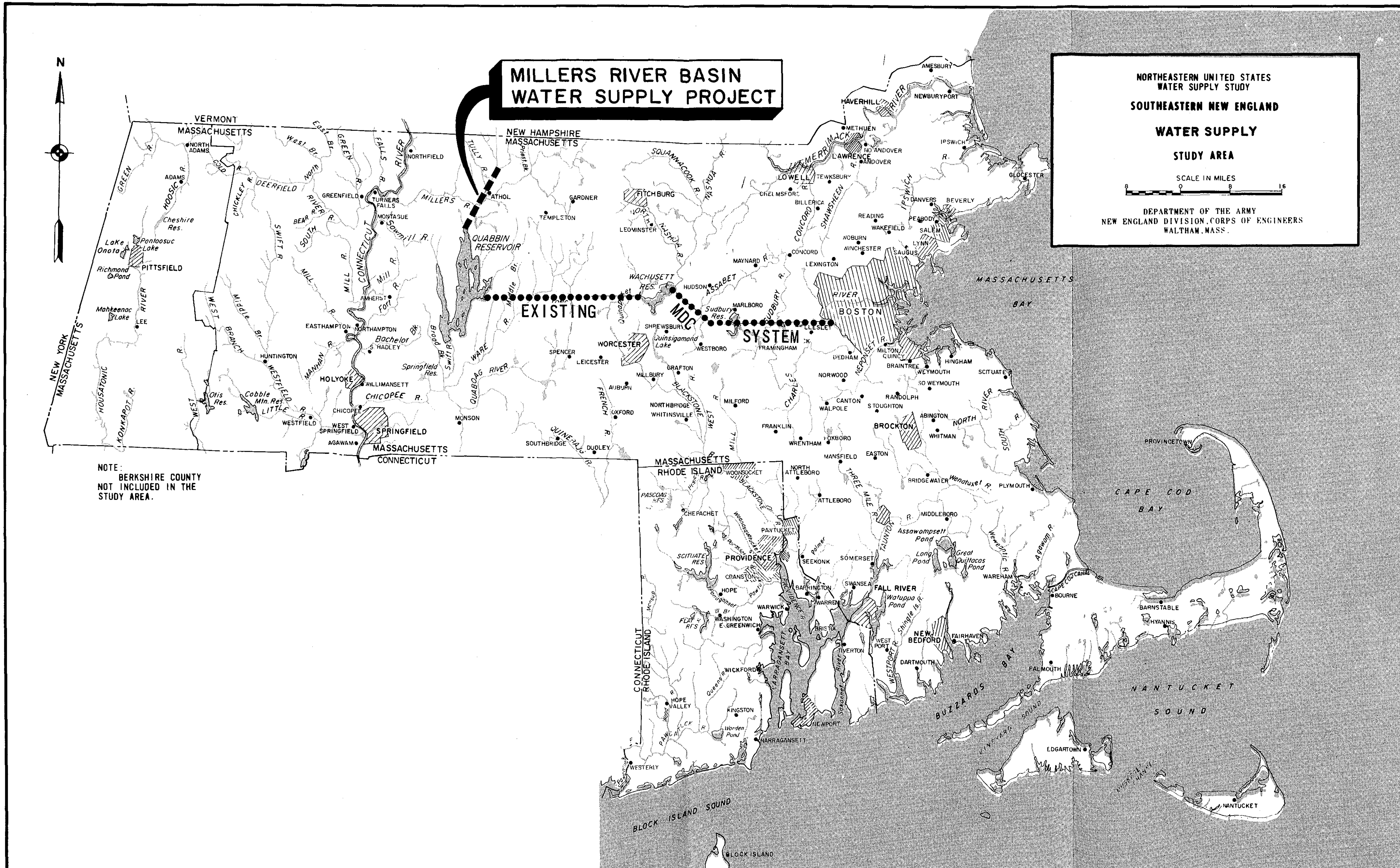
g) Estimates of quantities and costs of major items of construction.

h) Alternatives to the proposed project, ranging from the development of small local water supply sources to an assessment of desalination, waste water reuse and weather modifications.

i) Inclusion of multi-purpose applications within the proposed water supply project.

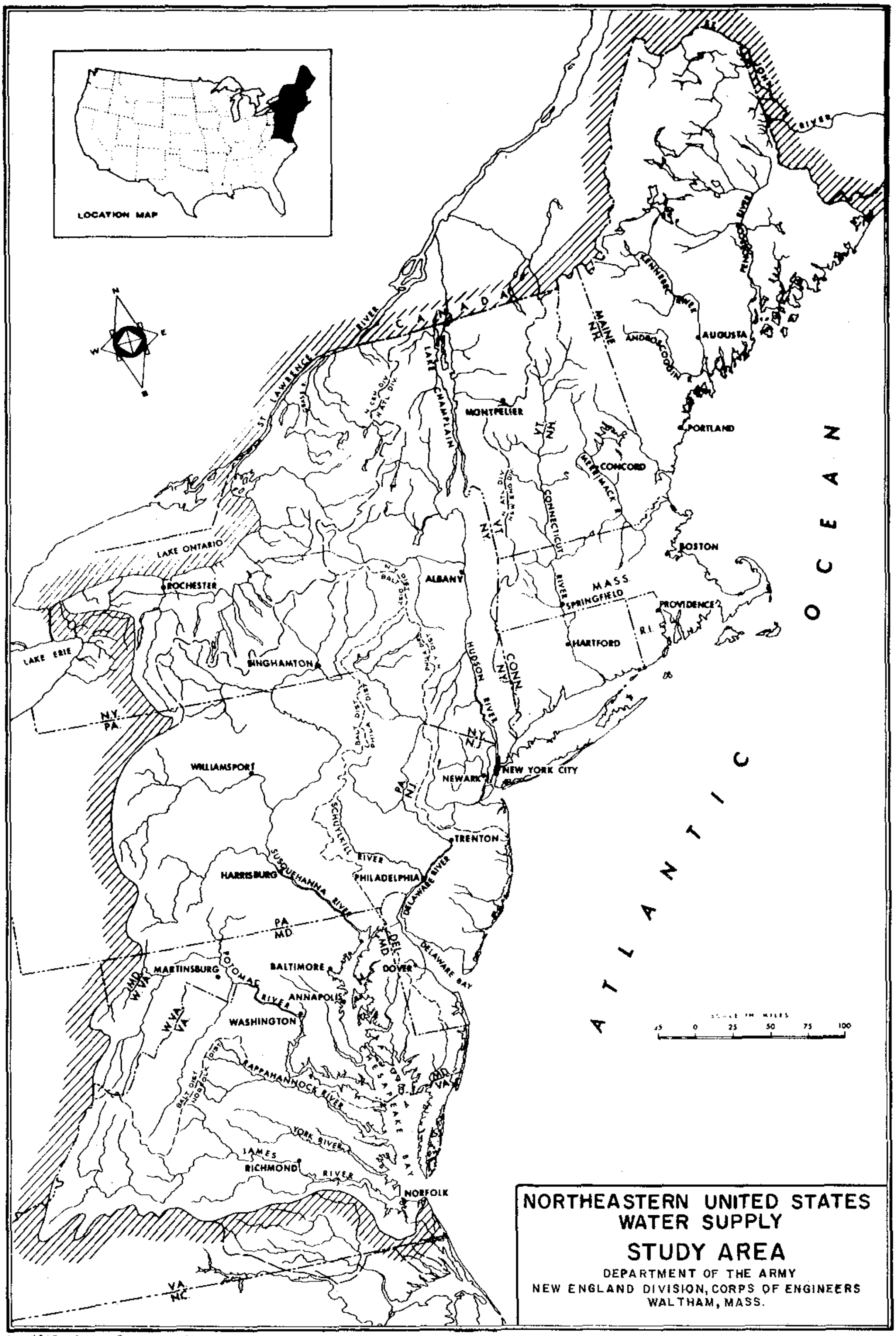
j) An investigation of the broad socio-economic impact of the proposed project.

Since the initiation of these studies, a determined effort has been made to inform the public of the work's progress. Beginning in May 1970, a total of six formal public meetings, nine progress and four informal informational meetings were held. At all of these meetings, progress on various elements of the NEWS Study was described.



MILLERS RIVER BASIN
WATER SUPPLY PROJECT
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
SOUTHEASTERN NEW ENGLAND
WATER SUPPLY
STUDY AREA
SCALE IN MILES
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
EXISTING MDC SYSTEM
NOTE:
BERKSHIRE COUNTY
NOT INCLUDED IN THE
STUDY AREA.
N
VERMONT
MASSACHUSETTS
NEW HAMPSHIRE
MASSACHUSETTS
NEW YORK
MASSACHUSETTS
MASSACHUSETTS
CONNECTICUT
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
RHODE ISLAND
QUABBIN RESERVOIR
WACHUSETT RES.
MASSACHUSETTS BAY
CAPE COD BAY
NANTUCKET SOUND
BUZZARDS BAY
BLOCK ISLAND SOUND
BOSTON
WORCESTER
SPRINGFIELD
PROVIDENCE
FALL RIVER
NEW BEDFORD
BROCKTON
HOLYOKE
PITTSFIELD
LOWELL
LAWRENCE
FITCHBURG
ATHOL
NEWPORT
NANTUCKET
EDGARTOWN
BLOCK ISLAND

PLATE I



NORTHEASTERN UNITED STATES
WATER SUPPLY
STUDY AREA
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

June 1969 - US Army, Corps of Engineers

PLATE 2

Questions, answers and opinions were interchanged between the study team and audience. Input gained at these meetings served to guide the direction of the tasks and the final recommendations.

At the November 1971 progress meeting, a number of citizens stated a desire for formation of a "Citizens Participation Board." The purpose of this group was to act as an ombudsman for citizens in the watershed from which diversion of water was contemplated. Initiated in December 1971, this board has worked with members of the study team to insure that views and concerns of the watershed citizens were known throughout the conduct of this study.

SECTION II

PRIOR REPORTS

4. Published Reports

A. General

A large number of reports have been prepared on the various rivers within the Connecticut River Basin. These reports, prepared by Federal, State and Regional Agencies, cover many areas of resource interest, both in the public and private sectors. In the Corps of Engineers on-going flood control program, for example, there have been completed, beginning in calendar year 1926 and continuing through 1968, a total of 25 reports in response to separate Congressional directives. In the area of navigation, from 1911 through 1969, the Corps had submitted 18 separate reports, while six summary reports on flood plan information have been submitted as guides to local municipalities. In addition, two multi-purpose flood control reservoirs recently constructed have included water supply storage under the provisions of the Water Supply Act of 1958. Few of these prior Federal reports, however, address themselves to water supply planning, thus a complete listing was not considered necessary for this report. A few of the more pertinent Federal reports are included in the following section.

State and Regional Planning Agencies, however, have been active in preparing plans for future water supply needs. Wherever applicable, these reports have been reviewed and considered in the preparation of this study. A listing, including these agencies and some of their reports, is given in paragraphs 4 C. and 4 D.

B. Federal

The land and water resources and flood control needs have been considered in the following published reports:

1) "308" Report, dated 11 February 1936, was submitted to Congress with recommendations which included the construction of ten flood control reservoirs on the tributaries of the Connecticut River in the states of Vermont and New Hampshire.

2) "House Document 455, Seventy-fifth Congress, 2nd Session" was published in 1937. This report proposed a revised comprehensive plan for flood control of the Connecticut River and its

tributaries consisting of 20 reservoirs and dikes at seven locations. The report recommended that the authorization for additional reservoirs be deferred and that the authorized project be modified to provide for the protection by dikes and related works of cities.

3) "The Resources of New England - New York Region," as authorized in Section 205 of the Flood Control Act of 1950 (P. L. 516-81st Congress, Second Session) together with a Presidential Directive of 9 October 1950, establishing a six-member Federal interagency committee. This report recommended that the river basin and regional plans set forth in the report serve as a guide for the development, conservation, and utilization of land, water, and related resources of the New England - New York Region. The report is commonly referred to as NENYIAC. Part I and Chapter I of Part 2 are printed as SD 14, 85th Congress, 1st Session.

4) "Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin," was published in June 1970. This report was authorized in resolution of the Committee on Public Works of the United States Senate, adopted 11 May 1962. The purpose of the report is to present a comprehensive plan of development that will serve as a flexible guide for the optimum utilization of the water and related land resources of the basin. Specific objectives of the studies made for this report were: to isolate the basin's problems and potentials related to its water and land resources; to develop possible solutions to these problems and formulate from them projects and programs to satisfy the immediate (1980) and to identify potential measures for long-range (2020) needs.

The study was directed and reviewed by the Connecticut River Basin Coordinating Committee composed of representatives of the Departments of Agriculture; Army; Commerce; Health, Education and Welfare; and the Interior; the Federal Power Commission; and the States of New Hampshire; Vermont; Massachusetts; Connecticut; and the New England River Basins Commission.

In formulating a plan to meet the needs and desires of the people in the Connecticut River Basin, the Coordinating Committee strove to insure that all elements be compatible and that programs and projects be flexible and adaptable to unforeseen demands and changing patterns of needs. Alternatives were given due and responsible consideration.

The Committee developed a plan to accomodate two time frames; namely, an "early action" plan covering the next ten years; and a long-range framework type plan embracing requirements and opportunities to the year 2020. The 1980 Basin Plan, as recommended by the Coordinating Committee, is estimated to cost $1,800,000,000 (based on 1969 price levels). The proposals are presented in ten broad element categories as follows: Water Quality, Power, Outdoor Recreation, Preservation of Sites, Anadromous Fisheries Restoration, Resident Fish and Wildlife, Water Supply, Navigation, Upstream Water and Related Land Resource Potential, and Flood Control and Large Multiple-Purpose Reservoirs.

The water supply element of the 1980 Basin Plan is presented in five parts, four of which concern water supply requirements for the four basin States and part number five in regard to out of basin diversion of water supply.

Water supply needs are presented for each of the basin States in detail. The study finds that the natural abundance of available surface and groundwater supplies, if properly developed, can meet all projected municipal and industrial needs of the basin. Out of basin needs for the 1980 time period are recognized as being met by flood-skimming operations such as that proposed in conjunction with the Northfield Mountain pump storage power project. Similar flood-skimming operations potential was identified at the existing Corps of Engineers' Tully Reservoir located in the Millers River watershed.

Thus the need for, and potential of, servicing out of basin water supply demands from the Connecticut Basin was identified in the comprehensive study. The Millers River Basin Water Supply Project, described in this report, therefore, is compatible[1] with the comprehensive Basin Plan.

5) "North Atlantic Regional Water Resources Study" was published in June 1972. This report was authorized in Section 208, Public Law 89-298, 27 October 1965. The purpose of the report was to present a comprehensive framework plan for the management of water, related land and other environmental resources in the North Atlantic Region of the nation, a region which closely approximates the NEWS study area.

The study was directed and reviewed by the North Atlantic Region Water Resources Study Coordinating Committee. This Coordinating Committee was comprised of representatives of the Departments of Agriculture; Army; Commerce; Housing and Urban Development; Interior; Transportation; Environmental Protection Agency; and the Federal Power Commission. The States of Vermont, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania,

(1) See New England River Basins Commission letter of 15 June 1973 in Appendix N.

Delaware, Maryland, West Virginia, and Virginia also served on the Committee as well as representatives of the District of Columbia, Delaware River Basin Commission and the New England River Basins Commission.

The Coordinating Committee used a multiple objective planning process to consider alternative objectives, needs, devices, benefits and costs to develop a 50-year management program for the Region's water and related land resources. Answers to all questions are not provided in this report. As a framework document only, guideposts are presented that will lead its users to more direct routes in finding answers related to water resources management and will lead users away from or warn them of potential pitfalls.

6) "Organizational, Legal and Public Finance Aspects of Water Supply for Southeastern New England the Metropolitan Area of New York City - Northern New Jersey - Western Connecticut," July 1972. This report was prepared as part of the overall Northeastern United States Water Supply Study (NEWS). The purpose of this report was to analyze organizational, legal, and economic problems of water supply within the study area. Alternative solutions to the problems are described and discussed.

The results of engineering studies supplemented by the results of this institutional feasibility study constitute the tools with which the Corps of Engineers and other agencies and organizations concerned may reach a decision on which of the various alternatives more detailed study effort should be concentrated.

7) In addition to the published reports described in the previous paragraphs, a report entitled "Feasibility Report on Alternative Regional Water Supply Plans for Southeastern New England" was recently prepared by the New England Division Division for the North Atlantic Division as part of the Northeastern United States Water Supply Study (NEWS). This report, as described in the summary, assesses the capability of the public water supply systems within eastern Massachusetts and Rhode Island to meet future needs. Plans and alternatives are proposed which when added to the present systems, would assure future adequate water supply for the study area.

C. <u>State</u>

1) <u>Massachusetts</u>

Massachusetts State Agencies with responsibility in water supply planning, construction and certification are the Department of Natural

Resources, the Metropolitan District Commission, and the Department of Public Health.

Studies regarding the present water supply situation in the Boston Metropolitan Region have provided a significant input to the preparation of this report. Some of the regional reports include:

a) Massachusetts Senate Document No. 1216, Report of the Metropolitan District Commission to Make an Investigation and Study Relative to Increasing the Sources of Water to the Metropolitan Water District and Increasing Membership of Said District, December 1971.

b) Hill and Lind, Inc., Report on Ipswich River District Water Supply, Prepared for the Massachusetts Water Resources Commission, Division of Water Resources, September 1971.

c) Massachusetts Senate Document No. 1008, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water From Millers River and Other Sources Into Quabbin Reservoir, March 1971.

d) Massachusetts House Document No. 5543, Report of the Special Commission Relative to Providing Funds for Extension and Development of Water Supply Sources and Diversion of Water from Connecticut River to Quabbin Reservoir, May 1970.

e) Massachusetts Senate Document No. 1230, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water From Millers and Other Sources Into Quabbin Reservoir As Required by Chapter 46, 1967, March 1969.

f) Massachusetts Senate Document No. 1095, Report of the Metropolitan District Commission Relative to the Diversion of Excess Water from Millers River and Other Sources into Quabbin Reservoir, December 1966.

g) Massachusetts Senate Document No. 808, Special Report of the Metropolitan District Commission Relative to Diversion of Excess Water from Millers River into Quabbin Reservoir, January 1966.

h) Massachusetts House Document No. 4100, The Public Water Supply Resources of the Ipswich River, Prepared for the Massachusetts Water Resources Commission, Division of Water Resources, January 1965.

2) Connecticut

In the State of Connecticut, responsibility for the adequacy and safety of public drinking water supplies lies with the Connecticut Department of Public Health. In addition to this agency's work, a large amount of regional water supply planning has been conducted by regional planning agencies and the private investor-owned water supply companies. In 1967, an Interagency Water Resources Planning Board was formed to coordinate and report the State's water resources. The agencies which make up the Board are the Office of Statewide Planning, Department of Environmental Protection and the Department of Public Health. Reports prepared by Connecticut State Agencies and reviewed as part of this study include:

a) Statewide Long Range Plan for the Management of the Water Resources of Connecticut, Phase I, Prepared by the Interagency Water Resources Planning Board, 1971.

b) Dewey and Kropper, Engineers, Inc., Effect of Proposed Northfield Mountain Diversion Project on State of Connecticut's Interests, Prepared for Connecticut Water Resources Commission, May 1966.

D. Regional Planning Agencies

Seven regional planning agencies in Massachusetts and Connecticut are located in the vicinity of and downstream from this study's project area. Those within Massachusetts are the Franklin County, Department of Planning and the Lower Pioneer Valley Regional Planning Commission. Within Connecticut, five agencies have been active. They are the Capitol Region, Midstate, Central Connecticut, Connecticut River Estuary and Southeastern Connecticut Regional Planning Agencies. A number of reports regarding future water supplies of the agencies' respective regions have been prepared and include:

1) Unpublished Report on Water Supply Needs in Franklin County, Massachusetts, 1971.

2) Metcalf and Eddy, Engineers, Inc., Water Supply Facilities, Prepared for the Lower Pioneer Valley Regional Planning Commission, March 1970.

3) James S. Minges and Associates, Alternative Plans for Regional Utilities Study, Prepared for the Capitol Region Planning Agency, June 1968.

4) Maguire, Charles A. and Associates, Regional Water Supply and Distribution in the Central Connecticut Planning Region, Prepared for the Central Connecticut Regional Planning Agency, March 1969.

5) Water Supply Plan for the Southeastern Connecticut Region, Volume 2, Recommended Plan, Prepared by the Southeastern Connecticut Water Authority and the Southeastern Connecticut Regional Planning Agency, February 1970.

In addition to reports prepared by planning groups in the Connecticut River Basin, water supply studies prepared by regional groups in eastern and central Massachusetts were also reviewed. These included:

6) Camp, Dresser and McKee Engineers, Inc., Alternative Regional Water Supply Systems For the Boston Metropolitan Area, Prepared for Metropolitan Area Planning Council, February 1971.

7) Metcalf and Eddy Engineers, Inc., Water Supply and Sewage Planning in Central Merrimack Valley Region, Prepared for Central Merrimack Valley Regional Planning Commission, September 1970.

8) Northern Middlesex Area Commission, Regional Utilities, Volume 2, Alternative Plans for Sewer and Water Facilities, July 1969.

9) Metcalf and Eddy Engineers, Inc., Report to Old Colony Planning Council, Brockton, Massachusetts, on Phase Three of Water and Sewerage Study, March 1971.

10) Tippetts - Abbett - McCarthy - Stratton, Regional Study for Water Supply, Sewerage Disposal and Drainage, Southeastern Massachusetts, Phase II, Prepared for Southeastern Massachusetts Regional Planning Commission, April 1969.

11) Maguire, Charles A. and Associates, Regional Water System Study, Prepared for the Connecticut River Estuary Regional Planning Agency, April 1972.

SECTION III

COORDINATION

5. Project Coordination

The study effort provided for direct participation and coordination by Federal, State and local agencies as well as interested conservation and citizen groups. To achieve full participation by all interested, a series of formal public meetings, progress meetings and informal informational meetings was employed.

All of these meetings and extensive letter communications furnished the principal means of contact with the public. Appendix M describes these meetings in detail including summaries of the statements made.

A. Public Meetings

A total of 13 formal public meetings were held within New England during the studies. Seven meetings were held at the outset of the NEWS investigations in May and June 1967. These meetings were held in all six New England States at Springfield and Waltham, Massachusetts; Portland, Maine; Concord, New Hampshire; Montpelier, Vermont; Bloomfield, Connecticut; and Providence, Rhode Island. At these meetings the background leading to the Northeastern United States Water Supply Study and the studies' objectives described. Citizen input was solicited and questions on the study were answered.

During December 1971 and January 1972, a series of four formulation stage public meetings were held in Needham, Woburn, Orange, and Longmeadow, Massachusetts. These meetings were designed to broaden public participation in the open planning process by describing on-going studies and receiving audience input. Some people spoke in favor of the plans presented. Others thought that we should concentrate on reducing demand instead of diverting more water to Eastern Massachusetts. A number of people at the Orange meeting suggested that water be diverted from the Millers River itself after pollution abatement. This suggestion has since been incorporated into the study and included as part of the preferred plan.

In July 1972 two late stage public meetings were held in Waltham and Orange, Massachusetts. At these meetings, the results of the NEWS investigations were described. Advantages and shortcomings of the alternative proposals for meeting short-range water supply needs were outlined and discussed. Audience input at these meetings ranged from approval of the projects described as most advantageous to requests for modification of various elements and in some cases opposition to any of the diversions proposed.

A court stenographer was employed to provide permanent records of all three series of meetings. An abstract of the results of these meetings is given in Appendix M.

B. Progress Meetings

Since the initiation of these studies, a determined effort has been made to inform the public of the work's progress. Nine progress meetings were held in the Boston Metropolitan area, generally at Waltham, Massachusetts, the first held on 7 May 1970, with the latest held on 7 June 1972. Attendance at these meetings generally averaged about 50 people, with attendees representing Federal and State Agencies, conservation commissions, the Audubon Society, sportsmen groups, and interested citizens. Progress on various elements of the NEWS study was described by the study team. In an informal atmosphere, questions, answers and opinions were interchanged between the study team and audience. Input gained at these meetings served to guide the direction of the study and the final recommendations.

C. Information Meetings

In addition to the progress meetings, four informal information meetings were held within the Millers River Basin. These meetings were held in Athol, Massachusetts on 21 October 1971 and 4 January 1972, and in Winchendon, Massachusetts on 2 March 1972, and in Athol, Massachusetts on 8 May 1972. These meetings were held at the request of local government or citizens' groups and offered a further opportunity for public understanding of the study and public participation in its conduct.

D. Citizens' Participation Board

At the November progress meeting, a number of citizens stated a desire for formation of a "Citizens' Participation Board." The purpose of this Board was to act as an ombudsman for citizens in the watershed from which diversion of water was contemplated. Initiated in December 1971, this Board has worked with members of the study team to insure that views of the watershed citizens were known throughout the conduct of the study.

SECTION IV

PHYSIOGRAPHY - TULLY AND MILLERS BASIN

6. Location

The Millers River Basin is situated principally in north-central Massachusetts with its northern most portion located in southwestern New Hampshire. Above its mouth and confluence with the Connecticut River at Montague and Erving, Massachusetts, the Millers River drains some 392 square miles of watershed. The Tully River, one of the two major tributaries of the Millers River, drains approximately 74 square miles above its confluence with the Millers River at Athol, Massachusetts. The Tully River watershed is located north of Athol, Massachusetts principally in the northwestern section of Worcester County, Massachusetts, although its northern most portion does extend into southwestern New Hampshire. A plan of the basin is shown on Plate No. 3.

7. Natural Resources

A. Surface - Land Forms - Elevation

The Millers River Basin lies wholly within the New England upland physiographic province. To the west is the Connecticut Valley lowland and to the east the seaboard lowland. The elevations within the basin range from 200 feet above mean sea level at its western most point to about 1,400 feet above mean sea level in the east and northeastern sections. In general, the terrain is quite hilly, rugged and dotted with a number of small ponds and lakes and swampy depressions. Many of the swampy areas are ponds in the spring when the runoff and water table are high but revert to swamps again when the water table drops in the early summer. The topography is largely controlled by the structure and lithology of the underlying bedrock and many of the tributaries follow structural trends in the bedrock. The northern basin divide is not static since differential crustal rebound has tilted the basin to the south. Hence, the northern tributaries have enlarged and will slowly continue to enlarge the northern portion of the basin.

B. Geology - Soil - Mineral Resources

Relief of the Millers River Basin is moderate with elevations on the till areas generally attaining 1,100 to 1,400 feet and 800 to 900 feet in the valleys. The topography of the region is largely controlled by the structure of the underlying igneous and metamorphic bedrock of the paleozoic era which has produced a general north-south trend of the valleys and ridges.

Glaciation has modified a preglacial bedrock topography by scour and moreso from glacial debris deposited by the ice and by melt-water streams. Glacial deposition has locally disarranged pre-glacial courses of drainage. Much of the region is covered by glacial till deposited directly by the ice and mantling the bedrock on the crests and upper slopes of the hills and thickest on the lower slopes and in the valleys. Overlying the till in the valleys are extensive glacial outwash deposits of sands and gravels in the form of kames, kame terraces, kame plains and ice-channel fillings.

The proposed retention reservoirs on the Priest and Tarbell Brooks and the West Branch Tully River will largely inundate glacio-fluvial deposits of sand and gravels. Since untapped deposits of this nature occur in abundance throughout the region, these three sites are of little commercial value.

C. Biological Productivity

The Millers River Basin is located in the south central portion of the Connecticut River Basin. The Connecticut River Basin has a number of life zones, areas containing a specialized system of plant and animals which have evolved through the years by means of climate and elevation. The Millers River Basin is within the Temperate Hardwood Forest zone, a zone characteristically hemlock - deciduous hardwood forests. Maple, beech, hemlock and pines are the dominant tree types in the area. White tailed deer, black bear, gray fox, gray squirrel and cotton tail rabbits are characteristic animals of these forests.

Some 22 species of fish are reported in the Millers River watershed. Population magnitude and locations are dependent on the particular

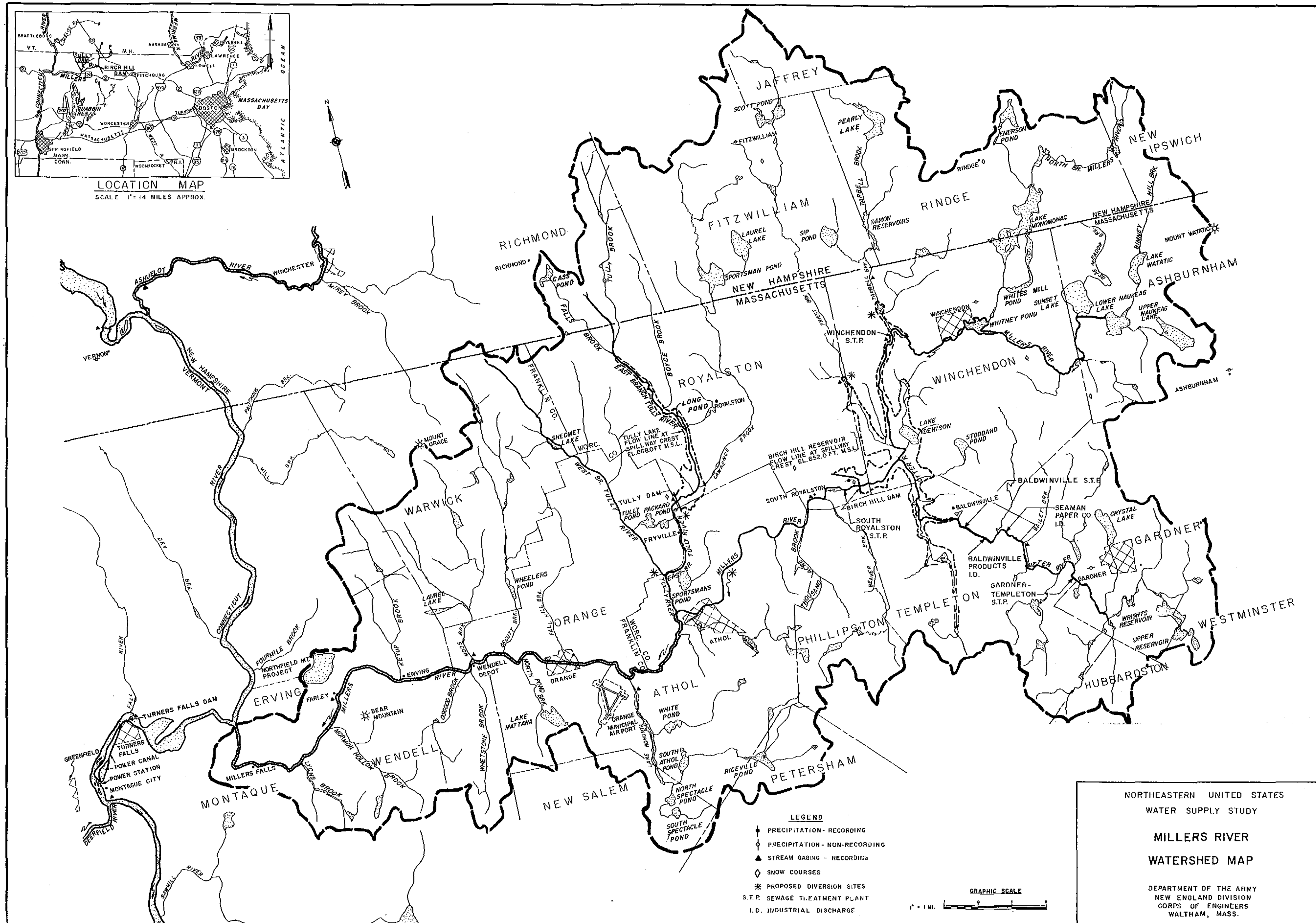

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
MILLERS RIVER
WATERSHED MAP
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.
LOCATION MAP
SCALE 1"= 14 MILES APPROX.
LEGEND
PRECIPITATION - RECORDING
PRECIPITATION - NON-RECORDING
STREAM GAGING - RECORDING
SNOW COURSES
PROPOSED DIVERSION SITES
S.T.P. SEWAGE TREATMENT PLANT
I.D. INDUSTRIAL DISCHARGE
GRAPHIC SCALE
1" = 1 MI.
JAFFREY
FITZWILLIAM
RINDGE
NEW IPSWICH
RICHMOND
ROYALSTON
WINCHENDON
ASHBURNHAM
WARWICK
ORANGE
ATHOL
PHILLIPSTON
TEMPLETON
GARDNER
WESTMINSTER
HUBBARDSTON
PETERSHAM
NEW SALEM
WENDELL
MONTAQUE
ERVING
NEW HAMPSHIRE
MASSACHUSETTS
VERMONT
MILLERS RIVER
CONNECTICUT RIVER
TULLY DAM
BIRCH HILL DAM
TURNERS FALLS DAM
NORTHFIELD MT. PROJECT
TULLY LAKE FLOW LINE AT SPILLWAY CREST EL. 668.0 FT. M.S.L.
BIRCH HILL RESERVOIR FLOW LINE AT SPILLWAY CREST EL. 852.0 FT. M.S.L.
WINCHENDON S.T.P.
BALDWINVILLE S.T.P.
SEAMAN PAPER CO. I.D.
BALDWINVILLE PRODUCTS I.D.
GARDNER-TEMPLETON S.T.P.
SOUTH ROYALSTON S.T.P.
LAKE DENISON
STODDARD POND
CRYSTAL LAKE
WRIGHTS RESERVOIR
UPPER RESERVOIR
LAKE WATATIC
MOUNT WATATIC
LOWER NAUKEAG LAKE
UPPER NAUKEAG LAKE
LAKE MONOMONAC
WHITNEY POND
LONG POND
LAUREL LAKE
PEARLY LAKE
CASS POND
SHEOMET LAKE
MOUNT GRACE
BEAR MOUNTAIN
LAKE MATTAWA
ORANGE MUNICIPAL AIRPORT
WHITE POND
SOUTH ATHOL POND
NORTH SPECTACLE POND
SOUTH SPECTACLE POND
RICEVILLE POND
MILLERS FALLS
TURNERS FALLS
POWER CANAL
POWER STATION
MONTAGUE CITY
GREENFIELD
VERNON
WINCHESTER
ASHUELOT RIVER
DEERFIELD RIVER
SAWMILL RIVER

PLATE 3

species requirements as well as the pollution stress. Several cold water species, such as trout, are now only found in the upstream water, while warm water species such as hornpout, yellow perch, bass, pickerel, blue-gills and sunfish have a wider distribution. The pollution abatement program will improve water quality and increase the fish population and locations.

D. Waste Discharges

The water quality within the Millers River Basin varies from excellent to quite poor. Water within the upper reaches of the watershed is of excellent quality due to the low level of development. However, once the mainstem river flows through Winchendon, Massachusetts, it is subjected to a variety of waste effluents until it merges with the Connecticut River. The mainstem of the Millers River contains treated effluent from Winchendon, untreated domestic sewage from South Royalston, Athol, Orange, and Erving, untreated sanitary wastes from industries located along the river banks, and industrial wastes from textile mills, foundries, paper mills and machine manufacturing concerns. The Otter River, the main southern tributary to the Millers River, contains treated effluent from Gardiner, untreated sewage from Baldwinsville, industrial wastes from plating plants, point manufacturing concerns, foundries and paper mills. Beaver Brook, a small southern tributary having its confluence with the Millers River near South Royalston, receives treated effluent from the Fernald State School in Templeton. For the most part, the other tributaries within the basin are relatively free of pollution. Principal points of pollution discharge in the upper watershed are shown on Plate No. 3.

E. Land Use

The Millers River has a drainage area of 392 square miles. Of this, 78 percent is forest, 11 percent open land, 8 percent wetland and 3 percent urban area. Ten towns and one city lie wholly or substantially within the watershed. The population density of about 160 persons per square mile is below average for this section of the Connecticut River basin. Agricultural use of the land is very limited and probably of less commercial importance than forest lands. There are a number of state forests and parks and two federal flood control projects within the basin. This coupled with the fact that Route 2, the "Mohawk Trail", traverses westerly through the basin makes the area a tourist center.

8. Climate

The Millers River Basin is located in the mid-latitudes and is influenced by storm systems moving easterly across the United States. The winds generally are northwesterly in winter and southwesterly in the summer. Exceptions are the prolonged plovial periods resulting from slow moving disturbances in the North Atlantic and infrequent tropical storms in summer and fall which cause heavy intense rain. The mean monthly temperatures of this area vary from about 25°F to 75°F with a mean annual temperature of approximately 48°F. The growing season averages about 120 to 140 days and occurs from the latter part of May to October.

Precipitation occurs as both rain and snow and, for long term averages, does not vary substantially from month to month. However, individual monthly totals may vary from no measurable precipitation to over 15-inches. The median annual precipitation is about 43-inches. Snowfall ranges from 40 to 70-inches. Maximum snowcover usually occurs in the latter part of February and lasts into early or mid-spring.

The largest most severe drought in the history of the basin occurred from 1961 to 1968 and effected the entire northeastern portion of the United States as well. The accumulated deficiency (below average annual) in rainfall within the basin for the above 6-year drought period was approximately 63 inches.

9. Water

A. Stream Characteristics

The Millers River rises in Ashburnham, Massachusetts and flows in a general westerly direction for about 45 miles through Winchendon, Athol, and Orange to its confluence with the Connecticut River at Montague and Erving, Massachusetts. It has a total fall of approximately 900 feet. The upper reaches of this river are fed by a number of small brooks, flowing in a southerly direction from the towns of Rindge and New Ipswich, New Hampshire. Important tributaries on the Millers River are the Tully River, Priest Brook, Tarbell Brook and the Otter River. The Tully River Basin has a total drainage area of approximately 74 square miles and has its confluence with the Millers River at Athol, Massachusetts. It has three major tributaries; namely, the East Branch, the West Branch and Lawrence Brook.

B. Flow and Runoff

The U. S. Geological Survey (USGS) has published records of river stages and streamflows at several locations in the Millers River Basin for various periods of time since 1914. Flow data at selected gaging stations including the station on the East Branch Tully River near Athol, are summarized in Table 1. Mean maximum and minimum monthly and annual runoff in cfs for the period of record for the Millers River at Erving, Massachusetts are shown in Table 2.

C. Reservoirs - Lakes - Ponds

There are two existing Corps of Engineers flood control dams and reservoirs in the Millers River Basin, Birch Hill on the Millers River about 27.5 miles above its mouth, and Tully on the Tully River approximately 4 miles above its mouth. In total, they regulate flood flows from some 225 square miles of watershed and provide about 71,900 acre-feet of storage. There are also a number of fairly large lakes and ponds within this region. A list of some of the larger areas and their approximate surface areas follows:

Lake or Pond	Town	Surface Area (acres)
Lake Rohunta	Athol, Mass.	291
Sportsman Pond	Fitzwilliam, N.H.	108
Laurel Lake	Fitzwilliam, N.H.	180
Lake Monomonac	Rindge, N.H.	592
Crystal Lake	Gardner, Mass.	158
Lower Naukeag Lake	Ashburnham, Mass.	291
Upper Naukeag Lake	Ashburnham, Mass.	243
Whitney Pond	Winchendon, Mass.	105

In addition, the basin is dotted throughout with smaller lakes and ponds.

TABLE 1

STREAMFLOW RECORDS
MILLERS RIVER BASIN

Location	Drainage Area (sq. mi.)	Period of Record	Mean Discharge CFS	MGD	CFS/ Sq. Mi.	MGD/ Sq. Mi.
Tarbell Brook near Winchendon	18.2	1916 - 1967	28.7	18.5	1.57	1.01
Millers River near Winchendon	83.0	1916 - 1967	138	89.1	1.66	1.07
Priest Brook near Winchendon	19.4	1916 - 1967	31.9	20.6	1.64	1.05
Millers River at South Royalston	187	1939 - 1967	301	194.4	1.61	1.04
East Branch Tully River near Athol	50.4	1915 - 1967	79.9	51.6	1.58	1.02
Millers River at Erving	375	1914 - 1967	608	392.7	1.62	1.04

TABLE 2

MONTHLY RUNOFF (CFS)

MILLERS RIVER BASIN

Month	Millers River at Erving, Mass. DA = 375 square miles 1915 - 1966			Priest Brook near Winchendon, Mass. DA = 19.4 square miles 1917 - 1966		
	Mean	Maximum	Minimum	Mean	Maximum	Minimum
January	601.6	1288	83.3	28.8	79	1.2
February	550.4	1486	132.1	23.8	81	5.3
March	1137.6	3989	364.0	64.4	199	13.6
April	1575.9	3584	631.6	95.5	225	27.6
May	816.9	1652	288.4	42.1	91	12.8
June	490.4	1641	92.5	23.7	124	2.5
July	296.3	1118	61.7	11.7	62	1.0
August	231.2	1052	52.6	9.2	68	0.5
September	285.5	3030	43.2	12.5	177	0.3
October	286.6	1286	74.0	13.6	62	0.6
November	476.9	1617	79.7	27.6	124	1.4
December	581.5	1543	82.5	30.7	94	4.7
Annual	608.0			31.9		

SECTION V

ECONOMIC DEVELOPMENT

10. Past Trends in Economic Growth

This section is drawn from data contained in Appendix A and describes the past changes in the economic growth of the source area, the Millers River Basin, and the service area, the Boston Metropolitan Region, and discusses the historical forces which have been influential in shaping their present-day characteristics. It sets the stage for the analysis of future economic growth of the Millers River and Boston Economic Areas. Using this data, an assessment of the future demand for water and related land resource goods and services in the study areas can then be made.

The towns of Deerfield, Greenfield and Gill, while not within the hydrologic boundary of the basin, are included in the Millers River Economic Area. Plate No. 4 shows this area and its three subregions. The area is predominantly rural in nature with moderate elevations and a terrain characterized mostly by rolling hills. Beginning with early settlements in the late 1600's, agriculture was the major industry with areas too steep for plowing used for sheep grazing. The abundance of water was a prime factor in the early development of industry in the region. At present, the industrialized areas are concentrated in the central and eastern sectors. Manufacturing, as it has since the early 1900's, contributes heavily to the economy of the area. Machinery, fabricated metals, paper and allied products, textile mill products and food and kindred products are the major manufacturing sectors in the region.

In 1969, the major water using industries, as shown on Table No. employed 2,808 persons. This represented 40 percent of the total manufacturing employment in the Millers River Economic Area for that year. Excluding textiles, which was the only major water using industry to show a long-term trend in decreasing employment, the remaining industries experienced a net gain of 755 employees or a relative increase of approximately 31 percent between 1956 and 1967. However, from 1967 to 1969 these industries experienced a decrease in employment reflecting the influence of national economic and social forces which dominate any regional economic activity.

The Lower Millers River Economic Subregion represented as Subregion I on Plate No. 4 is sparsely populated relative to the rest of Massachusetts and includes only one large town, that of Greenfield, with a 1970

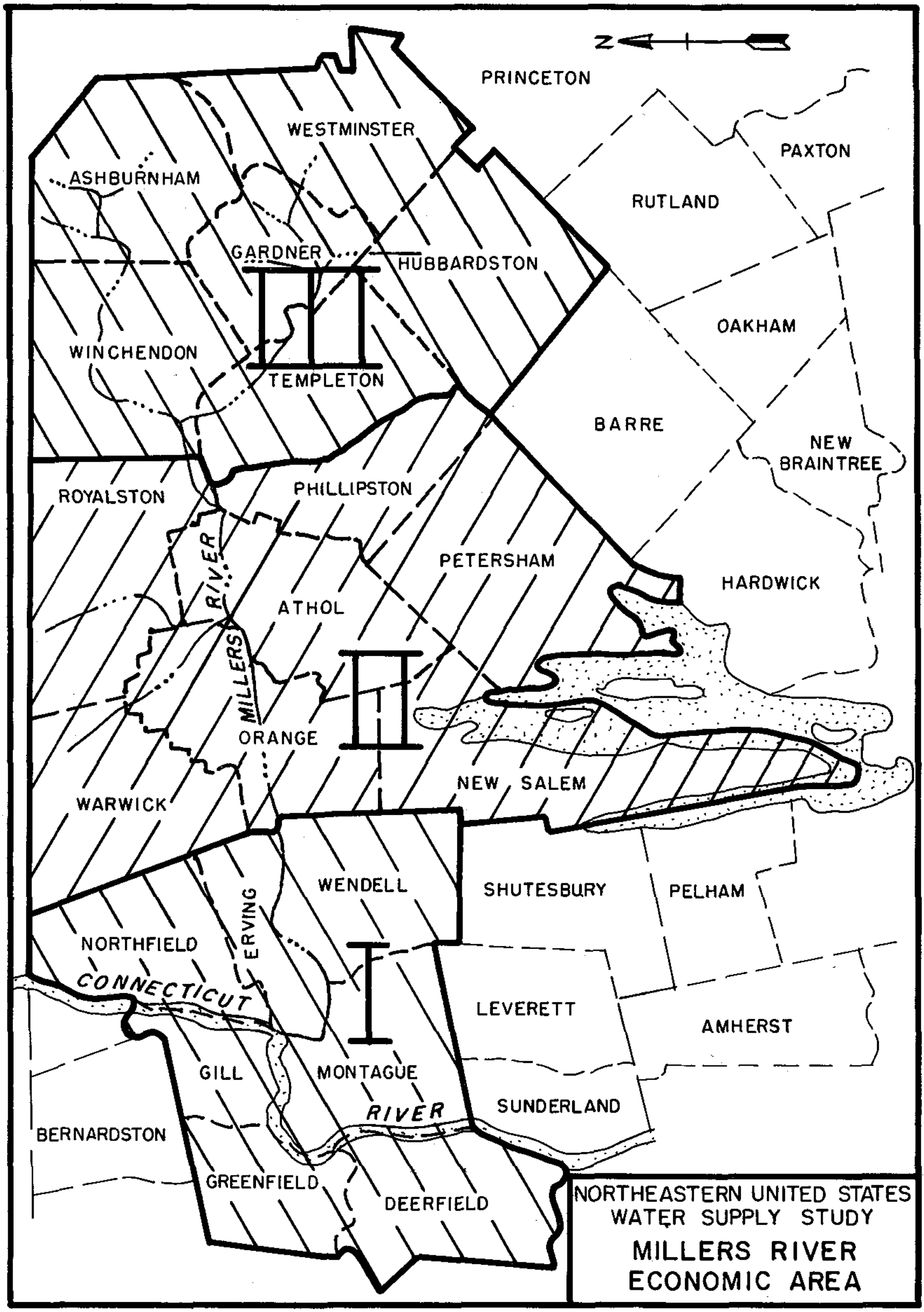

N
PRINCETON
WESTMINSTER
PAXTON
ASHBURNHAM
RUTLAND
GARDNER
HUBBARDSTON
III
OAKHAM
WINCHENDON
TEMPLETON
BARRE
NEW
BRAINTREE
ROYALSTON
PHILLIPSTON
RIVER
PETERSHAM
HARDWICK
ATHOL
MILLERS
II
ORANGE
NEW SALEM
WARWICK
WENDELL
SHUTESBURY
PELHAM
ERVING
NORTHFIELD
I
CONNECTICUT
LEVERETT
AMHERST
GILL
MONTAGUE
RIVER
SUNDERLAND
BERNARDSTON
GREENFIELD
DEERFIELD
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
MILLERS RIVER
ECONOMIC AREA

PLATE 4

population of 18,084. Lying within the fertile Connecticut River Valley, the Lower Millers is extensively forested and has substantial farmlands. However, manufacturing still contributes heavily to the economy with over 50 percent of the total employment mainly concentrated in the machinery, fabricated metal products, precision hand and electric tools and paper and allied products sectors.

The Middle Millers River Economic Subregion, shown on Plate No. 4 as Subregion II, is for the most part agricultural and residential in nature with manufacturing centered in Athol and Orange. This subregion, like subregion I, is extensively forested and has substantial farmlands. But the employment pattern of the area is centered more heavily on manufacturing with nearly 75 percent of the total employment involved in this sector of the economy. As opposed to the Lower and Upper Millers River Economic Subregions, the average annual rate of population growth for the Middle subregion has been somewhat lower. During the 1960-1970 period, the rate was negative while remaining positive for the other subregions.

The Upper Millers River Economic Subregion, Subregion III on Plate No. 4, is sparsely populated and includes only one large city, that of Gardner, with a 1970 population of 19,513. Because of the rocky surface in many areas of the subregion, farming was never profitable, but dairying, fruit-growing, and poultry raising are still carried on. Manufacturing, as in the two other subregions, is by far the largest source of employment with concentrations in the manufacture of furniture and fixtures, toys, sporting and athletic goods, fabricated structural metal products and office and store machines and devices. As a matter of fact, Gardner is known as "the Chair City of the World."

In essence, each subregion is different from the others, confronted by its own problems and having differing capabilities which influence its prospects for future growth. Differences relate primarily to the resources and production facilities in a region, the structure of its economic activity, and the characteristics of its population, work force and industrial sectors.

On the other hand, the service area, the Boston Metropolitan Area, was one of the earliest settled areas of the United States and has for many years experienced a high level of urbanization. Only in recent years, however, have the outer most towns of the area begun to feel the urban pressures. Like the Millers River Economic Area, farming was the principal occupation of early settlers and the abundance of water power was a vital factor in the industrialization of the area.

However, the Boston Area also had good marine resources and soon became one of the most important commercial and trade centers on the east coast.

Today, the Boston Metropolitan Area is geographically and economically the center of the largest employment and population cluster in New England. This cluster is the northern terminus of "megalopolis", the Atlantic coastal strip between Washington and Boston, in which live approximately one-fifth of the United State's population. Boston, the central city, is the Massachusetts State capitol, the most populous city in New England, and the center of the eighth largest SMSA in the country. While only secondarily a manufacturing center, the city's primary function in the area is as a trade and finance center. In the economic area as a whole, however, manufacturing has the largest share of total employment, followed by the service industries. Specialization occurs in miscellaneous manufacturing, electrical machinery, textiles, professional services, trade and construction. In recent years, the Boston area has experienced a remarkable growth in technologically-oriented industries which have located here in response to, or as spinoffs of, the concentration of advanced eduction and research facilities.

11. Measures of Economic Activity

Economic changes can be measured by a set of interrelated variables, namely, population, labor force employment, personal income and net output. These indicators express in economic terms the need for water resource development in an area. Especially important are the numbers of people projected to live in an area and any expected changes in industrial activity.

National projections of the overall economy were made in terms of benchmark aggregates such as gross national product, population, personal income and employment. From these summary measures were derived national totals of the economic series to be projected for local areas. Implicit in this procedure is the fact that national forces clearly cominate economic development throughout the nation. Because of the lack of gross area product data which could be compared to gross national product data, other indications of economic activity at the regional level are utilized. Employment data available in detail at the regional level are used to indicate changes in industrial activity and total personal income provides an overall measure of regional economic growth.

12. Projected Economic Growth.

Projections are based on extensions of past relationships believed to have future relevance for the measures being projected. Underlying these extensions of past relationships are assumptions that make the projections conditional forecasts. For instance, it is assumed the Federal government will implement policies needed to maintain relatively full employment and avoid prolonged levels of inflation and that the economy will be free of the distoring effects of a major military conflict during the 50-uear projections interval. It is assumed that water will play the same role in stimulating or depressing economic growth in the future as it has in the past.

In general, the examined historical data and projections derived indicate that both the Millers River and Boston Metropolitan Area econonomies will continue to expand and prosper in the period 1970-2020. The projected rates of expansion for the two regiona, however, differ markedly. In the process of expansion, both areas will continue to export valuable services and/or manufactured goods beyond their boundaries. Changes within and around the areas' various economic sectors are, of course, inevitable and will play a dominated role in determining the regions' growth paths. Population, urbanization, employment, personal income and the nature and co-position of the industrial and business mix of the economies will all be of special relevance to the diverse water resource problems and needs of the two areas.

Population in the Millers River Economic Area is expected to increase from 97,600 in 1970 by a factor of 1.45 to 141,300 people by the year 2020, although a decline is anticipated in relation to the total population of New England from 0.84 percent to 0.71 percent of the six-state figure. At the same time, populated in the Boston Metropolitan Area is expected to increase from 3,652,000 in 1970 by a factor of 1.7 to 6,126,000 by the year 2020. Here again, a decline is anticipated in relation to the total population of New England from 31.3 percent to 30.9 percent of the six-state figure.

Total personal income in the Millers River Economic area is expected to rise by a factor of 4.9 by the end of the projection period. Since the area's population will be 1.45 times greater, per capita personal income will rise over threefold. At the same time, total personal income in the Boston Metropolitan Area is projected to increase by a factor of 6.3. Thus, per capita personal income in the Boston Area will increase closer to fourfold over the projection period.

The manufacturing sectors in both the Millers River economic area and the Boston Metropolitan Area are projected to decline relative to the non-manufacturing sectors in importance as sources of employment. Employment in Franklin County's manufacturing industries is expected to drop from 33 percent of total employment in 1970 to roughly 25 percent by the year 2020. In the Boston Area, manufacturing employment as a percentage of total employment is projected to decline from 29 percent to 20 percent over the projection interval. By the year 2020, there will be more employees in non-manufacturing jobs than in manufacturing positions in both areas. Employment in the services is expected to increase 93 percent by the year 2020 in Franklin County and 153 percent in the Boston Metropolitan Area. Expanding population and rising personal income indicate further advances for urban services such as finance, insurance, real estate and medicine and health in the Boston Metropolitan Area. Thus, the projections of manufacturing employment show the structural shifts which both economies are expected to experience.

The major water using industries in both the source and service area include food and kindred products, textile mill products, chemical and allied products, petroleum refining and primary metals industries. Employment in each one of these major water using industries for the Boston Water Resources Planning Area, which includes the Worcester County portion of the Millers River Economic area, and for the Millers River Economic Area are shown in Tables 3. 4 and 5. In the Boston Water Resources Planning Area employment in food, textiles and petroleum are projected to decrease greatly while a slight increase in employment is expected in the chemical, paper and primary metal industries. Within the Hartford-Springfield Economic area which includes Franklin County employment in the chemical and paper industries is expected to more than double by 2020. The Millers River Economic Area has a total of 2, 800 people employed in the water using industries while the Boston area has a total of 171, 400 employed. This is sixty times as many people as in the Millers River Economic Area. In both the OBE Economic Areas, the economic production per employee is projected to dramatically increase an indicated by Tables 6 and 7. Therefore, the economic production in dollars for the water using industries in both areas is actually increasing. But in absolute terms the projection of the Boston area far exceeds the Millers River.

The largest segment of the Millers River economic region's population growth is expected to be in the Upeer Millers subregion in northwestern Worcester County which lies adjacent to the Fitchburg-Leominster Metropolitan Area. Population in this subregion is projected to increase by 58 percent as opposed to 39 percent for the

TABLE 3

EMPLOYMENT BY MANUFACTURING GROUPS
BOSTON WATER RESOURCES PLANNING AREA
(NAR AREA 0106)

INDUSTRY	1959	1970	1980	1990	2000	2010	2020
Food	53,178	44,900	41,300	37,600	35,700	34,100	33,000
Textiles	75,478	50,600	39,200	31,800	25,800	21,200	17,700
Chemicals	16,069	18,600	20,300	21,800	24,600	27,000	29,000
Paper	24,837	26,600	28,800	30,600	32,900	35,300	36,700
Petroleum	3,187	1,800	1,300	900	700	500	300
Primary Metals	25,841	28,900	31,300	33,200	35,300	37,100	38,800

TABLE 4

EMPLOYMENT BY MANUFACTURING GROUPS
HARTFORD-SPRINGFIELD WATER RESOURCES PLANNING AREA
(NAR AREA 0107)

INDUSTRY	1959	1970	1980	1990	2000	2010	2020
Food	20,832	19,500	19,200	19,100	18,900	18,700	18,700
Textiles	25,716	21,800	17,700	14,500	12,100	10,100	8,600
Chemicals	18,033	22,500	26,600	31,100	38,100	45,200	52,200
Paper	21,440	24,800	28,400	31,300	34,400	37,700	40,800
Petroleum	1,181	1,000	900	700	600	600	500
Primary Metals	29,305	26,200	22,800	19,800	17,600	16,600	16,000

TABLE 5

MILLERS RIVER ECONOMIC AREA

	1956	1958	1962	1964	1967	1969
Food, Tobacco Process	222	266	368	369	370	315
Textiles, Apparel Leather	1,167	1,037	873	821	702	670
Chemicals	74	77	113	121	134	35
Paper	1,306	1,581	1,598	1,730	1,759	1,660
Primary Metals	92	103	110	151	186	128
TOTALS	2,861	3,064	3,062	3,192	3,151	2,808

Source: Massachusetts Division of Employment Security

TABLE 6

Economic Production Per Employee (1958 Dollars)
Boston Economic Area (OBE Economic Area 004)

INDUSTRY	1960	1970	1980	1990	2000	2010	2020
Food	6,952	10,053	14,357	19,378	25,997	35,107	47,750
Textiles	4,602	7,353	10,921	15,714	22,680	32,438	46,262
Paper	7,365	10,170	13,106	16,576	21,051	26,542	33,804
Chemicals	9,232	16,287	26,295	41,148	68,124	97,891	133,356
Petroleum	7,573	20,623	42,297	81,856	155,240	280,181	502,761
Primary Metals	9,322	13,207	17,333	22,015	27,670	35,011	45,346

TABLE 7

Economic Production per Employee (1958 Dollars)
Lower Connecticut River Economic Area (OBE Economic Area 005)

INDUSTRY	1960	1970	1980	1990	2000	2010	2020
Food	7,958	11,059	15,363	20,384	27,003	36,113	48,756
Textiles	5,514	8,265	11,833	16,626	23,592	33,350	47,174
Paper	8,048	10,853	13,789	17,259	21,734	27,225	34,487
Chemicals	10,760	17,815	27,823	42,676	69,652	99,419	134,884
Petroleum	7,877	20,927	42,601	82,160	155,544	280,485	503,065
Primary Metals	9,642	13,527	17,653	22,335	27,990	35,331	45,666

Lower Millers and 29 percent for the Middle subregion. In absolute numbers, this represents a growth of 23,770 persons as opposed to 13,900 and 6,000 for the Lower and Middle subregions respectively. The increase in population projected for the Upper Millers River economic subregion is based on the labor force needs to meet the requirements of the Fitchburg-Leominster and Gardner economies which the regional labor force cannot accommodate. Since population settles or expands in a region primarily because of employment opportunities, a migration into the area is projected based on the assumption that labor shortages will be avoided and economic activity not curtailed. Thus, in view of the Upper Millers River subregion communities' positions surrounding Gardner, their closeness to the industrialized Fitchburg-Leominster Metropolitan area for commuting, and also, the open land availability, this subregion is projected to experience the largest population increase in the Millers River economic region.

Thus, each area is expected to expand considerably by the year 2020. However, the rate and magnitude of expansions vary markedly. The Boston Metropolitan Area has nearly 30 times more people residing in the area and is expanding at a rate nearly twice that of the Millers River area. Furthermore, the major water using industries in the Boston Metropolitan area employ over 60 times as many people as the Millers River Economic Area.

SECTION VI

THE WATER SUPPLY SETTING

13. General

A. Sixties Drought

As recognized in the NEWS Legislation, natural departures from normal precipitation and runoff conditions can have regional impacts on the social well-being of a large segment of the nation's population.

The long-term normal rainfall in southeastern New England is about 42 inches per year. This "normal" condition is actually the average of many high and low rainfall years. When rainfall is below average for a period of time, the area experiences a drought. The recent drought of the sixties in southeastern New England, for its duration, was the greatest ever experienced in the region based on over 200 years of rainfall record.

Because of the severity of this drought, many water supply systems were required to re-evaluate the dependable yield which their facilities could be relied on to produce. For example, the Metropolitan District Commission which, based on previous drought conditions, had estimated available sources at 330 million gallons per day (mgd) revised their dependable yield figure downward to 300 mgd.

The sixties' drought which began in 1961 when precipitation and water levels fell below normal, ultimately through its duration, directly affected the water use patterns of more than 20 million people. In 1965 alone, drought related water shortages and associated problems were severe enough to warrant emergency actions by local, state and Federal agencies. Within Massachusetts, more than 50 cities and towns imposed restrictions on water use.

B. Water Supply Agency Action

During and following the drought, a number of communities and regional planning agencies conducted engineering studies to determine methods for augmenting their existing supplies. In many cases, new supplies have been developed by the communities which would allow them to meet future supply needs. Investigations conducted by NEWS in the southeastern New England region, however, indicate that even with the actions undertaken by local authorities, additional supplies must be made available.

It is anticipated that as water requirements increase and local water resources are fully developed, particularly in urban areas, many municipal systems will likely join some of the major systems, such as the Metropolitan District Commission (MDC) and increase the regional character of these systems. A description of the MDC system is given in the following paragraphs.

14. Existing Regional System - Metropolitan District Commission - (Boston)

The Metropolitan District Commission (Boston) is the largest regional system within New England. At present, this system supplies either wholly or partially the water supply needs of 42 communities within the Commonwealth of Massachusetts. Consumers of the serviced population number about two million or fully 37 percent of the Commonwealth's 1970 population.

Existing dependable yield of the system is estimated to be 300 mgd. Average daily water consumption furnished by the system in 1971 was 322 million gallons per day (thus the system is outstripping available supply) of which 273 mgd was delivered to municipalities which rely exclusively upon the MDC as their only supply source. A plan of the communities is shown on Plate No. 5.

The MDC relies upon surface water as its supply source. Three major reservoirs: Quabbin, Wachusett and Sudbury impound flow from tributaries of both the Connecticut and Merrimack River Basins. A plan showing the location of these reservoirs and interconnecting aqueducts is shown on Plate No. 6.

The Quabbin Reservoir, located in the center of Worcester County, is the backbone of the MDC system. It impounds the runoff from 186 square miles of the Swift River Watershed and flow diverted from 98 square miles of the Ware River Watershed, both tributaries of the Connecticut River. It has a capacity of 412 billion gallons at full reservoir elevation and is approximately 18 miles long.

The water from Quabbin Reservoir flows through the Quabbin Aqueduct for a distance of 24.6 miles to the upper end of Wachusett Reservoir in West Boylston. This aqueduct, which is "horseshoe" shaped, is excavated through solid rock and line with concrete. Provisions have been made at the Ware River Intake Works at Coldbrook to divert the

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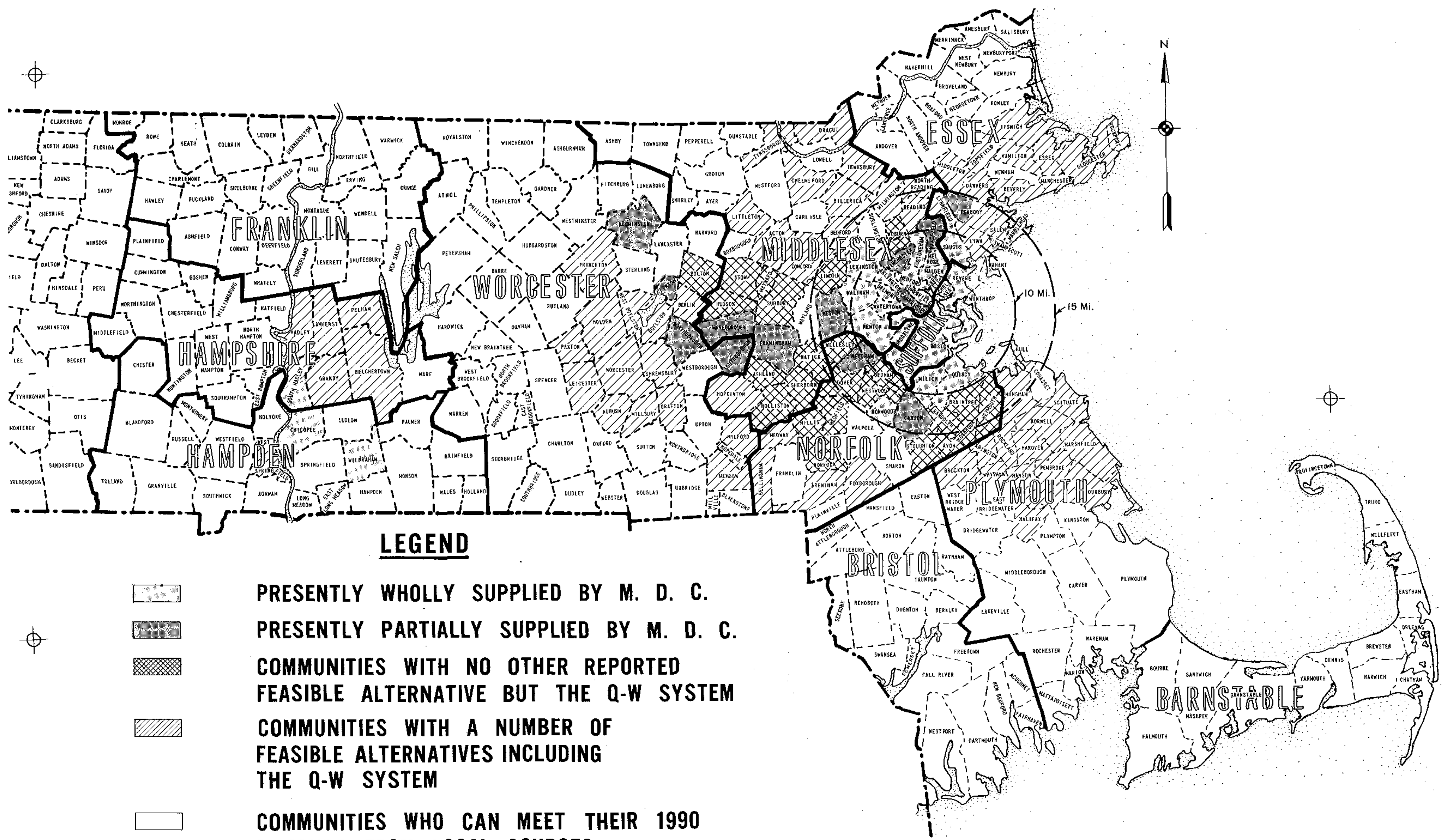


LEGEND

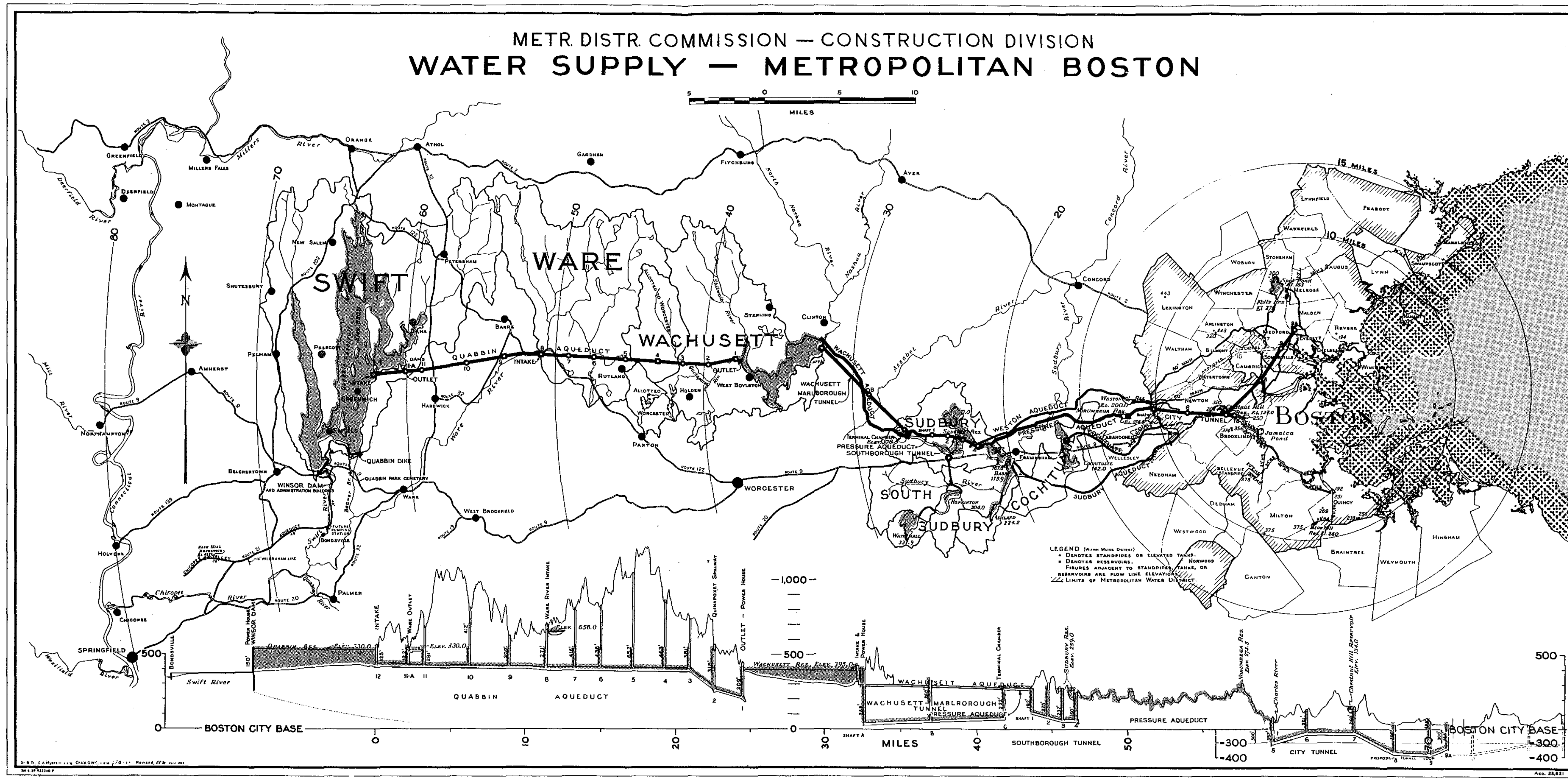
- PRESENTLY WHOLLY SUPPLIED BY M. D. C.
- PRESENTLY PARTIALLY SUPPLIED BY M. D. C.
- COMMUNITIES WITH NO OTHER REPORTED FEASIBLE ALTERNATIVE BUT THE Q-W SYSTEM
- COMMUNITIES WITH A NUMBER OF FEASIBLE ALTERNATIVES INCLUDING THE Q-W SYSTEM
- COMMUNITIES WHO CAN MEET THEIR 1990 DEMANDS FROM LOCAL SOURCES OR OTHER REGIONAL SYSTEMS
- EXISTING Q-W SERVICE AREA
- PROBABLE 1990 Q-W SERVICE AREA
- POSSIBLE 1990 Q-W SERVICE AREA

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
QUABBIN – WACHUSETT
WATER SUPPLY SYSTEM
EXISTING AND FUTURE SERVICE AREA

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORP OF ENGINEERS
WALTHAM, MASS.

PLATE 5

CORPS OF ENGINEERS U. S. ARMY



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

METROPOLITAN DISTRICT COMMISSION
EXISTING WATER SUPPLY SYSTEM

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE-6

flood flows from approximately 98 square miles of the Ware River Watershed into the aqueduct for storage in either the Quabbin Reservoir or the Wachusett Reservoir. Under ordinary circumstances, the water is diverted directly to the Quabbin Reservoir for storage and then is drawn back into the Wachusett Reservoir as occasion requires.

The Wachusett Reservoir on the Nashua River, a tributary of the Merrimack River, above Clinton, was the principal reservoir of the MDC system prior to the construction of Quabbin Reservoir. It has a watershed of 107.7 square miles and a capacity of 65 billion gallons. It is approximately 8.4 miles long with a surface area of 6.5 square miles.

The water has two means of conveyance from Wachusett Reservoir -- the Wachusett Aqueduct and the recently completed Wachusett - Marlborough tunnel. The Wachusett Aqueduct consists of a rock tunnel section 2 miles in length, a brick and masonry conduit, "horseshoe" shaped, 7 miles in length and an open channel section of 20 feet wide at the bottom and 3 miles in length. The open channel section terminates in the Sudbury Reservoir in Southborough.

The major portion of the water supplied by the Wachusett Aqueduct is diverted at a diversion dam on the open channel section of the aqueduct in Marlborough into the Hultman Aqueduct. The remaining water flows into the Sudbury Reservoir.

The Sudbury Reservoir is situated on the north branch of the Sudbury River and impounds the runoff of approximately 22 square miles of watershed; has a storage capacity of approximately 7 billion gallons.

During summer months, large quantities of water flow from this reservoir through the Sudbury Aqueduct to the Chestnut Hill Reservoir in Brighton. From there, it is pumped into the distribution system.

The new Wachusett-Marlborough Aqueduct is a deep rock concrete lined tunnel, 8.0 miles long. It extends from the Wachusett Reservoir to the Hultman Aqueduct intake structure. The major portion of the water supply requirements of the Metropolitan Water District is delivered through this aqueduct to the Hultman Aqueduct and thence to the Norumbega and Weston distribution reservoirs.

The Hultman Aqueduct begins at the previously mentioned diversion dam located on the open channel section of the Wachusett Aqueduct. It extends from this point 22.7 miles in an easterly direction to the Chestnut Hill Reservoir and pumping stations. This aqueduct consists of cut and cover concrete conduit and a section of hardrock tunnel. At the

Sudbury Dam, it is interconnected to the Weston Aqueduct which is a cut and cover conduit extending to the low pressure service Weston Reservoir.

From an intake shaft at Norumbega, the City tunnel runs a distance of approximately 5 miles to a point in the vicinity of the Chestnut Hill Reservoir in Boston, where it is connected directly to several large distribution mains which convey the water to several of the communities serviced by the Low Service, Southern High and Southern Extra High distribution systems. The City tunnel, reduced from 12 feet to 10 feet in diameter, extends from Chestnut Hill Reservoir, a distance of approximately 7 miles, to a point in Malden, where it is connected directly into large distribution mains which convey the water to other communities serviced by the Low Service and Northern High Service distribution systems. Presently, construction of an additional deep rock tunnel, extending from Chestnut Hill Reservoir in Boston to a point in the vicinity of the Boston-Milton town line at Dorchester Lower Mills, is under way. The completed construction of this tunnel will enable the Commission to improve pressures in its Southern High Service distribution system.

The Chicopee Valley Aqueduct, consisting of 36 and 48 inch pipe, conveys water from the Quabbin Reservoir to the town of Wilbraham, South Hadley Fire District No. 1, and the city of Chicopee, extends from the outlet works of Winsor Dam to the Keating Hill Standpipe of the city of Chicopee.

Water supplied to consumers in the Metropolitan Water District is treated with small amounts of chlorine and ammonia as it enters the distribution system. Occasionally it is necessary to treat some of the storage and distribution reservoirs with small amounts of copper sulphate in order to combat algae growths which materialize from time to time. The Water Division of the Metropolitan District Commission maintains three laboratories, one at the Quabbin Reservoir, another in Framingham, and a third in Boston.

Pertinent data on the three major source reservoirs is shown in the following table:

TABLE 8

METROPOLITAN DISTRICT COMMISSION
SYSTEM SOURCES

	Location	Drainage Area Sq. Mi.	Storage Capacity (mg)
Sudbury:	Southborough Marlborough	22.0	7,000
Wachusett:	West Boylston Sterling Clinton Boylston	107.7	65,000
Quabbin:	New Salem Petersham Hardwick Ware Belchertown	284.8 [1]	412,000
	TOTAL	414.5	484,000

[1] Includes 96.8 square miles of Ware River Watershed

15. Local Resource Potential

A. General

In estimating needs which might be required of the existing regional supply system (MDC), the role which locally available resources might play was investigated. The majority of new communities reported in this study as requiring connection to the regional system to meet future needs was the result of engineering studies[1] conducted by the Metropolitan Area Planning Council (MAPC). The MAPC comprises 98 municipalities in the Boston Metropolitan Region which include the majority of presently serviced MDC communities and the MDC's future short-range customers. In the following paragraphs, a brief summary of the MAPC engineering studies pertaining to local resource potential development is given.

"The purpose of this study is to identify and evaluate alternative water supply systems which may be developed to satisfy the water supply demands of the communities in the Council District through the year 1990. These systems would supplement the existing and potential local supply systems. The need for supplementing the existing supplies of most of the communities within the District was concluded from investigations conducted in conjunction with the 1969 Needs and Proposals report.

These investigations indicated that, of the 98 communities in the Council, only two communities had existing supplies capable of meeting projected 1990 demands, and only 17 communities outside of the communities served by the Metropolitan District Commission (MDC) reported potential supplies which, together with the existing supplies, could meet the 1990 demands.

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[1] Inventory of Water and Sewer Facilities, May 1967, Metropolitan Area Planning Council and Massachusetts Department of Commerce and Development, by Camp, Dresser & McKee, Consulting Engineers.

Projected Needs and Current Proposals for Water and Sewer Facilities, July 1969, Metropolitan Area Planning Council, by Camp, Dresser & McKee, Consulting Engineers.

Alternative Regional Water Supply Systems for the Boston Metropolitan Area, February 1971, Metropolitan Area Planning Council, by Camp, Dresser & McKee, Consulting Engineers.

The supplemental water systems discussed were developed along criteria and design guidelines chosen to be sufficiently generalized to permit use throughout the District, yet detailed enough to produce systems which were technically sound. The efficient development of a water supply system to meet the projected demands of the communities within the Council District will require further detailed studies of the most favorable alternatives presented in this study. All systems were developed without regard to institutional constraints. Particular emphasis was placed on the development of subdistrict systems which would serve a portion of the Council District through the utilization of local resources.

Five individual subdistricts were established as follows: the Charles River Subdistrict, the Concord River Subdistrict, the Ipswich River Subdistrict, the Neponset River Subdistrict, and the North River Subdistrict. A plan of the subdistricts is shown on Plate No. 7.

The supplemental needs of the individual communities were determined by comparing projected demands with the estimated safe yield of the existing and potential community supplies. Needs were assessed in accordance with the study policy that all local potential supplies were to be developed.

The needs may change in time as additional potential local supplies are discovered, or potential supplies must be abandoned.

It is emphasized that all potential groundwater sources must be fully explored, and development seriously considered even though the water is of quality that will require treatment.

B. Subdistrict Water Systems

The majority of the supplies to be developed to supply the subdistrict system will be surface supplies with either on or off stream reservoirs. It is imperative that before any of these alternatives are adopted, studies be conducted to investigate fully the environmental implications of these diversions.

1) Ipswich River Subdistrict: Two of the communities listed below have adequate existing supplies to meet their projected 1990 demands. An additional six communities have potential supplies which could adequately supplement their existing supplies through 1990. However, the potential supplies in five of the communities and the existing supplies in one of the communities make use of the Ipswich River.

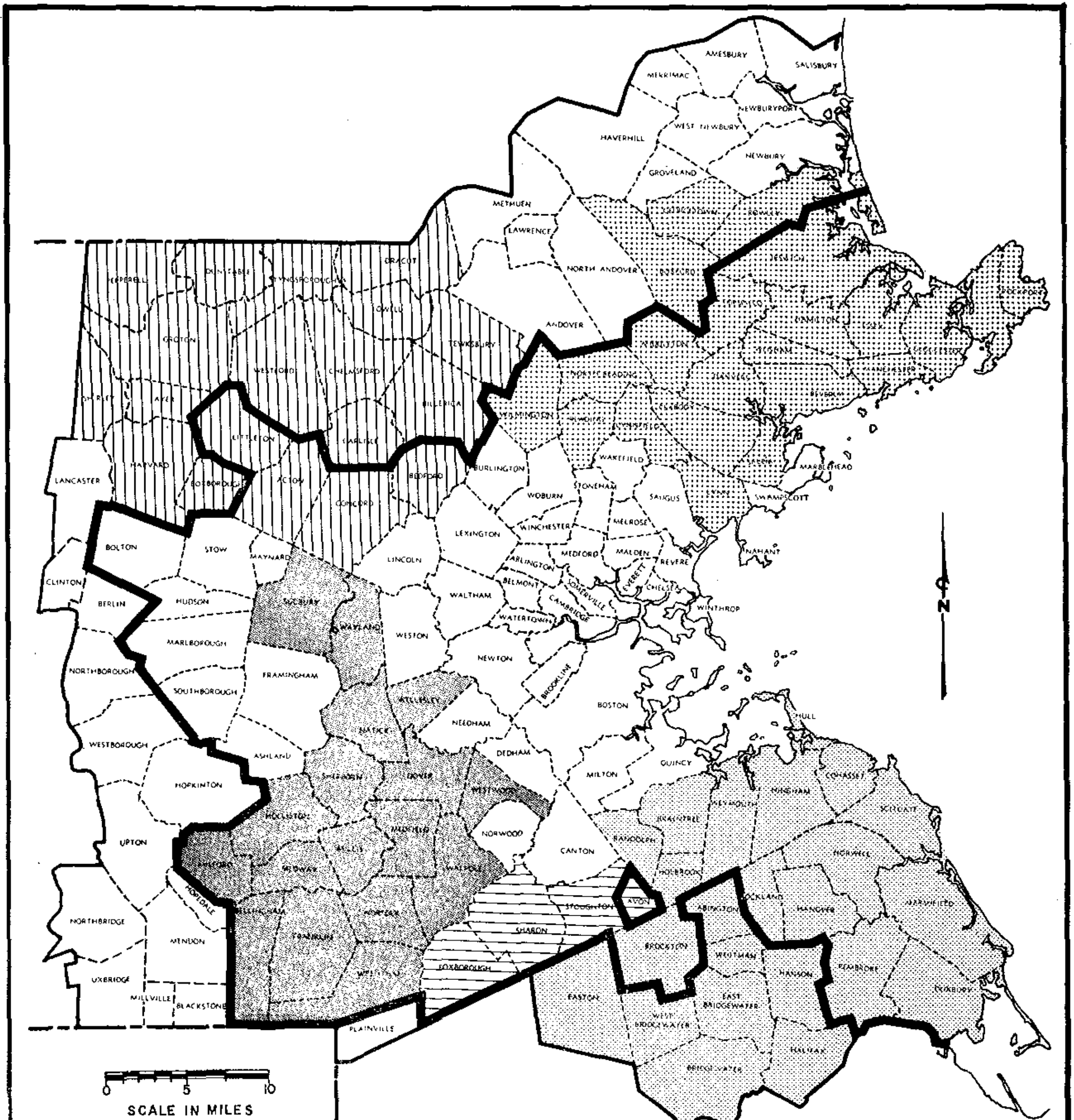
Beverly	Ipswich	Reading
Boxford*	Lynn	Rockport
Danvers	Lynnfield	Rowley*
Essex	Manchester	Salem
Georgetown*	Middleton	Topsfield
Gloucester	North Reading	Wenham
Hamilton	Peabody	Wilmington

*Not in Council District

The Ipswich River does not have the capacity to meet these collective demands. Unless the Ipswich River is supplemented, it will be unable to supply sufficient additional yield to even the communities which now pump from it. Through the construction of three new off-stream reservoirs, together with a diversion system from the Merrimack River, the Ipswich River can be developed to adequately supplement the existing and potential supplies of the communities in the Ipswich River Subdistrict. The Merrimack River is the only possible source which would permit diversion to the Ipswich during dry periods, thus reducing the size of the off-stream reservoirs required. The longer the period of diversion, the smaller the size of the reservoirs required to produce the same yield. Under present conditions, the diversion works would be located above the City of Lowell in the Town of Tyngsborough with water being transmitted about 17.6 miles to Lubber Brook in Wilmington, a tributary of the Ipswich. If the quality of the water in the Merrimack River was upgraded, the diversion works could be moved downstream to Andover, thus decreasing the length of the raw water transmission main.

Diversions would then be made from the Ipswich River at three general locations. At the first location, diversions would be made to a proposed 1800 million gallon (mg) regional reservoir in Lynnfield and to the existing Lynn and Peabody Reservoirs. The second diversion would occur downstream off Route 1 in Topsfield and would supply the proposed 1800 mg Topsfield reservoir. This new reservoir would be operated in conjunction with the existing facilities of the Salem and Beverly Water Supply Board. The third diversion would be located in Ipswich. Water would be pumped to the proposed 2800 mg Ipswich Reservoir.

2) Concord River Subdistrict: None of the MAPC communities in this subdistrict will be able to adequately meet their projected 1990 demands. However, the communities in the Concord River Subdistrict



LEGEND

- IPSWICH RIVER SUBDISTRICT
- CONCORD RIVER SUBDISTRICT
- CHARLES RIVER SUBDISTRICT
- NEPONSET RIVER SUBDISTRICT
- NORTH RIVER SUBDISTRICT

NOTE:

FROM <u>ALTERNATIVE REGIONAL WATER SUPPLY SYSTEMS FOR THE BOSTON METROPOLITAN AREA</u>, PREPARED FOR THE METROPOLITAN AREA PLANNING COUNCIL, BY CAMP, DRESSEN AND MCKEE, FEBRUARY 1971.

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

MAPC SUBDISTRICT AREAS

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

can also be supplied by the Merrimack River. This subdistrict includes four MAPC communities, Acton, Bedford, Concord and Littleton, and 13 communities adjacent to the Council District.

These communities would take their supply at the same location as the diversion works proposed for the Ipswich River Subdistrict mentioned above. The two pumping facilities may, in fact, be combined. If, however, both subdistrict systems are developed, it may be necessary to develop either additional storage facilities or a special working schedule to eliminate combined diverting during short periods of extreme low flows and thereby degrading water quality. The need will depend to a large degree on the number of the communities outside the MAPC District which would be supplied by the Concord River Subdistrict system.

3) Charles River Subdistrict: The third subdistrict considered includes the 17 communities in or adjacent to the Charles River watershed and listed below:

Bellingham	Milford	Walpole
Dover	Millis	Wayland
Franklin	Natick	Wellesley
Holliston	Norfolk	Westwood
Medfield	Sherborn	Wrentham
Medway	Sudbury	

Five of these communities can develop potential supplies to adequately meet their projected 1990 demands. The communities in this subdistrict have been subdivided into two groups, the Upper and the Middle Charles River Groups. By developing the abundant potential local supplies of Franklin and Milford and interconnecting the individual systems, the six communities in the Upper Charles River Group can adequately meet their projected 1990 demands. The 11 communities in the Middle Charles River Group can extend the adequacy of their systems by grouping together similar to the Upper Charles River Group.

However, unless the MDC is extended to supply Sudbury, Medfield, Norfolk and Dedham, the combined 1990 demands cannot be met even if all potential supplies are developed. Following the completion of the MAPC study, the NEWS study requested the opinion of the U. S. Geological Survey (USGS) concerning the hydraulic relationship of the well field proposed for the Middle Charles River Group and the River. The USGS replied they felt the proposed well fields were directly linked to the nearby river. With such a link, the well field in essence would be drawing from river flow, particularly in low flow periods. Low flow conditions in the Charles River at present are a critical factor in the river's water quality. It was felt that any substantial decrease in flow caused by withdrawals for water supply would increase water quality problems. Thus, the NEWS study proposed communities listed as middle Charles to be served by connection to the regional system.

4) Neponset River Subdistrict: Only the town of Sharon in this subdistrict, consisting of Avon, Foxborough, Sharon and Stoughton, can develop supply adequate through 1990. The remaining three subdistrict communities will require an outside supplementing source of supply. The projected 1990 demand of the Neponset River Subdistrict can be adequately met through the development of Ponkapoag Pond as a water supply reservoir. By raising the level of the Pond some 19 feet, adequate storage capacity can be provided to receive flood flows pumped from the Neponset River. Water would be pumped from the Neponset River only during periods when the flow exceeds 25 cubic feet per second (cfs). During dry periods, pumping will be permitted only over a few months of the year. In order to provide sufficient yield, it will be necessary to provide pumping capacity greatly in excess of the estimated safe yield of the system.

5) North River Subdistrict: The fifth subdistrict system investigated would provide supplemental supply to communities located south and southeast of Boston. This North River Subdistrict includes the 15 communities located in the MAPC District, listed below, plus the communities in the Old Colony Planning Council.

Braintree	Holbrook	Randolph
Cohasset	Hull	Rockland
Duxbury	Marshfield	Scituate
Hanover	Norwell	Stoughton
Hingham	Pembroke	Weymouth

Cohasset is the only member community which can develop supplies adequate through 1990. However, providing all of the communities develop their potential supplies, the North River could be developed to supply all of the communities in the subdistrict well beyond the year 1990 with the exception of the towns of Braintree, Weymouth, Randolph and Holbrook. While these communities could be supplied by the North River, it would be more realistic to supplement the supplies of these communities from the MDC, since they are remote from the North River, near the existing MDC system, and their demands would decrease the North River's period of adequacy. The only source that will be available to supplement the North River once the demands exceed its yield is the MDC, and these four communities would have to be connected to the MDC eventually.

Development of the North River for water supply purposes will require the construction of an on-stream storage reservoir located in the present tidal reach of the North River, a water treatment plant, and pumping and transmission facilities. It is recognized that an impoundment within the tidal reaches of the North River will affect the ecology of the estuary. Early estuarine studies should be made to determine the implications of ecological changes."

6) Summary: Certain groups of communities (particularly those outside Metropolitan Boston) can satisfy their present and projected 1990 needs without relying directly on the MDC. However, they cannot do so unless the MDC supplies certain key communities such as Sudbury, Medfield, Norfolk, Dedham, Braintree, Weymouth, Randolph and Holbrook. It, therefore, becomes apparent that any concept of regional supply for the eastern Massachusetts - Rhode Island Study Area depends on firming up the existing regional system, i.e. the MDC. This is the specific problem addressed by the present survey report.

Also by 1990, many communities not served by the MDC will collectively require water in addition to that available in their immediate watersheds. The development of institutions and physical systems to meet with this regional problem is critical. By 2020, the MDC will also require additional water from a large regional source. These two problems are the subjects of on-going studies.

16. Expected Expansion of the Regional System Service Area

Because potential new water supply sources within the Eastern Massachusetts area are rapidly becoming exhausted, communities are forced to look to regional concepts in water resource development as a means of meeting their future water supply needs. The MDC system represents the largest system in Massachusetts, and for this reason is expected to be called upon to expand its service area considerably by the year 1990.

Under present Massachusetts state Legislation, the MDC system is required to permit any municipality within 10 miles of the State House in Boston to become a member upon application. The MDC is further bound by the same legislation to allow any other municipality within 15 miles of the State House which could be reasonably serviced by the MDC to become, upon application, a member. Any non-member municipality with the approval of the Massachusetts Department of Public Health can be furnished water by the MDC.

In an attempt to determine what communities might be serviced by the regional system in 1990, four groups of municipalities were identified. These are listed below and shown on Plate No. 5.

1) Cities and towns presently serviced by the MDC.

2) Municipalities who cannot meet their future demands from local sources and who have no other reported feasible alternative but to join the MDC system.

3) Communities with a number of reported feasible alternatives including joining the MDC system.

4) Those cities and towns who can meet their future demands from local sources or from other regional systems not including the MDC system.

The MDC system presently is made up of 32 member communities, 25 of which are wholly served. The MDC also supplies water to 10 non-member communities which draw from either the Chicopee Aqueduct in the Springfield area or from the Wachusett-Sudbury reservoir system. These cities and towns, listed in Table 9, obtain water from the MDC because there simply are no other feasible sources of water supply available to them. Therefore, with the exception of Peabody, it has been assumed that all additional future water demands originating from these communities will be met completely by the MDC system. Peabody's additional demand may be met by further development of the Ipswich River.

The remaining communities in the study area were then investigated to determine if they can meet their 1990 water demand locally and then, if not, whether it is feasible for them to join the MDC system. The communities listed in Table 10 have no other reported feasible alternative to meet their additional future water demands other than joining the MDC system. Because they all can be reasonably served by the MDC, these cities and towns are included in the potential 1990 service area.

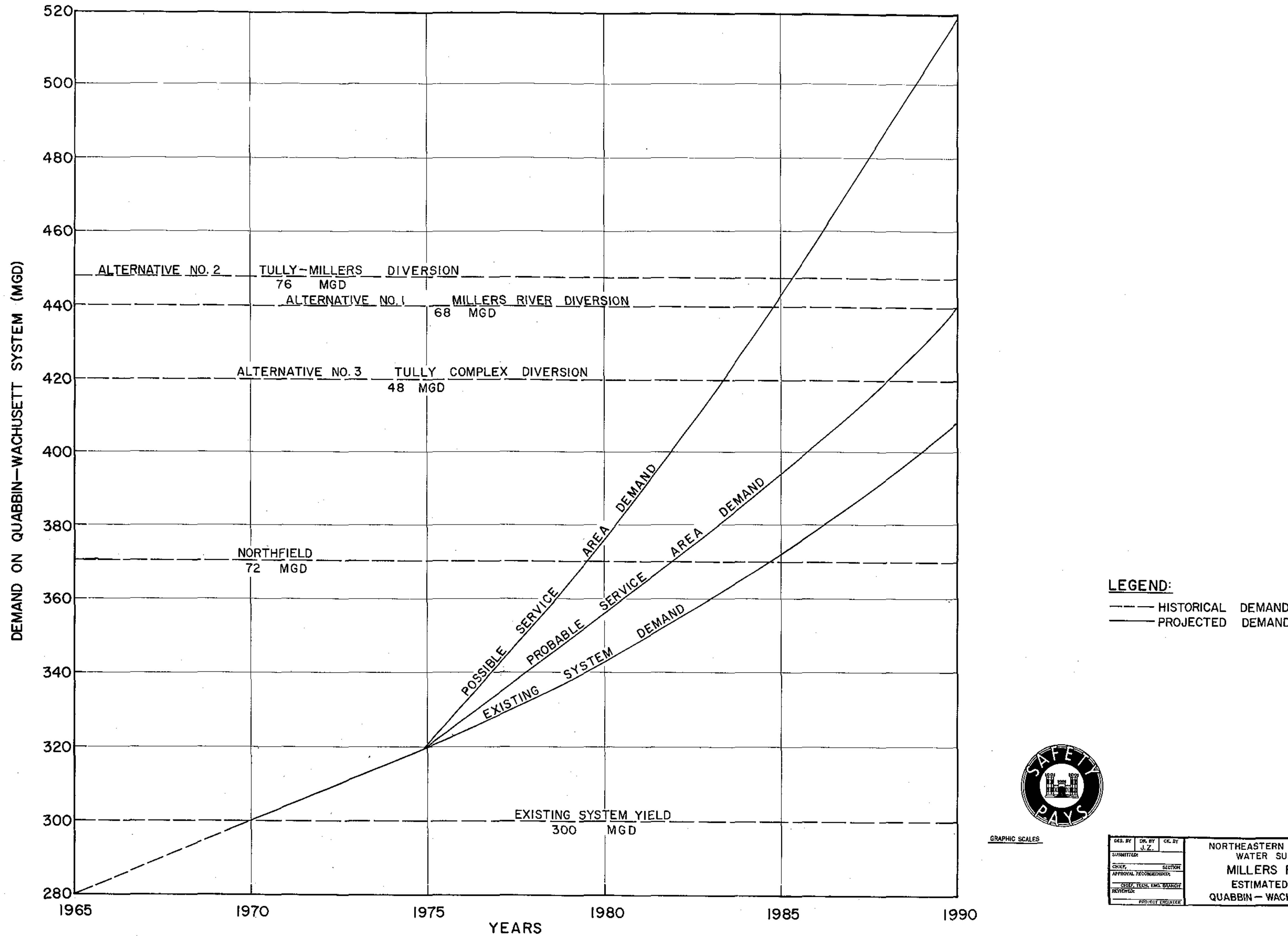
The third category of communities are listed in Table 11. These cities and towns have a number of feasible alternatives including connection to the MDC system. Other alternatives available to the municipalities include development of the Merrimack, Ipswich and North Rivers as well as ground water resources in some cases.

Those communities not anticipated to join the MDC system by 1990 are shown on Plate No. 5. Based on a review of these municipalities' 1990 water supply needs, it appears adequate local resource is available or entrance to another regional system is a more feasible solution.

The 1990 water demands on the Quabbin - Wachusett Reservoirs (MDC system) were then estimated for the three groups of communities which may be serviced. Supply demand estimates, as described in Appendix B, were derived using both population and industrial output forecasts. Population increases were combined with estimates of future per capita usage to provide supply needs domestic, commercial and public usage. Industrial output forecasts using a water use per dollar output analysis allowed the estimation of supply needs for heavy water using industry. Both estimates were then combined to give total future water requirements.

Once the supply requirements were established, the additional development necessary to meet these needs was determined. This was accomplished by subtracting safe yields of existing and anticipated supply sources from the total estimated needs. Using this methodology, the existing MDC's service area 1990 water demand was estimated to be about 410 million gallons per day (mgd). If the cities and towns with no other reported alternative were to join the MDC, total demand for 1990 was estimated to be about 441 mgd. If all communities noted as including the MDC as an alternative source were serviced, then 519 mgd would be needed in 1990.

Based on the investigations conducted in this report then the 1990 water supply needs to be met by the MDC could vary from a minimum of 410 mgd to a possible maximum of about 519 mgd. Although it is possible that all communities described as having other potential sources may elect to join the MDC system, it is unlikely. Based on efforts observed by this group, it appears that certain communities are willing and planning to develop the local resource to meet their needs. Providing additional supplies to non-MDC communities is part of the problem addressed by on-going NEWS studies. In this report, 1990 demands on the regional system estimated for presently served communities and those with no other reported option were used for planning purposes.



SAFETY PAYS

GRAPHIC SCALES

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
MILLERS RIVER BASIN
ESTIMATED DEMAND ON
QUABBIN – WACHUSETT SYSTEM

DR. BY J.Z.

TABLE 9

COMMUNITIES PRESENTLY BEING SERVICED
BY THE M.D.C.

FULLY SUPPLIED MEMBERS:

Arlington	Malden	Quincy
Belmont	Marblehead	Revere
Boston	Medford	Saugus
Brookline	Melrose	Somerville
Chelsea	Milton	Stoneham
Everett	Nahant	Swampscott
Lexington	Newton	Waltham
Lynnfield Water District	Norwood	Watertown
		Winthrop

PARTIALLY SUPPLIED MEMBERS:

Cambridge	Peabody
Canton	Wakefield
Needham	Weston
	Winchester

NON-MEMBERS SUPPLIED:

Clinton	Leominster	Southborough
Chicopee	Marlborough	South Hadley, F.D. #1
Framingham	Northborough	Wilbraham
		Worcester[1]

Total Estimated 1990 Demand	450 MGD
1965 Safe Yield[2]	335 MGD
Anticipated Expansion of Local Sources	5 MGD
1990 Deficit	110 MGD

[1] On an emergency basis only.

[2] Includes 300 MGD Safe Yield of Quabbin-Wachusett System.

TABLE 10

COMMUNITIES WITH NO OTHER REPORTED OPTION

Ashland	Millis
Avon	Natick
Bolton	Norfolk
Braintree	Randolph
Dedham	Sherborn
Dover	Stoughton
Holbrook	Stow
Holliston	Sudbury
Hudson	Wellesley
Lincoln	Westwood
Maynard	Weymouth
Medfield	Woburn

Total Estimated 1990 Demand	74 MGD
1965 Safe Yield	39 MGD
Potential Local Sources	4 MGD
1990 Deficit	31 MGD

TABLE 11

COMMUNITIES WITH OTHER OPTIONS INCLUDING THE M.D.C. SYSTEM

IPSWICH RIVER:

Beverly	Ipswich	Peabody
Danvers	Lynn	Reading
Essex	Lynnfield	Rockport
Gloucester	Middleton	Salem
Hamilton	North Reading	Topsfield
		Wilmington

Estimated 1990 Demand	58 MGD
1965 Safe Yield	47 MGD
1990 Deficit	11 MGD

CONCORD RIVER:

Acton	Concord
Bedford	Littleton

Estimated 1990 Demand	12 MGD
1965 Safe Yield	5 MGD
1990 Deficit	7 MGD

MERRIMACK RIVER:

Billerica	Dracut
Chelmsford	Tewksbury
	Tyngsborough

Estimated 1990 Demand	22 MGD
1965 Safe Yield	12 MGD
1990 Deficit	10 MGD

TABLE 11 (cont'd)

NORTH RIVER:

Abington	Hanson	Pembroke
Brockton	Hingham	Rockland
Duxbury	Hull	Scituate
Halifax	Marshfield	Whitman
Hanover	Norwell	

Estimated 1990 Demand	39 MGD
1965 Safe Yield	28 MGD
1990 Deficit	11 MGD

CHARLES RIVER:

Bellingham	Medway
Foxborough	Wrentham

Estimated 1990 Demand	9 MGD
1965 Safe Yield	5 MGD
1990 Deficit	4 MGD

MILL RIVER:

Hopedale	Mendon
Hopkington	Milford

Estimated 1990 Demand	6 MGD
1965 Safe Yield	2 MGD
1990 Deficit	4 MGD

TABLE 11 (cont'd)

WORCESTER AREA:

Auburn	Holden	Princeton
Berlin	Leicester	Shrewsbury
Boylston	Millbury	West Boylston
Grafton	Paxton	Worcester

Estimated 1990 Demand	47 MGD
1965 Safe Yield	26 MGD
1990 Deficit	21 MGD

COLLEGE AREA:

Amherst	Hadley
Belchertown	Pelham
Granby	South Hadley, F. D. #2

Estimated 1990 Demand	10 MGD
1965 Safe Yield	4 MGD
1990 Deficit	6 MGD

WEST SPRINGFIELD:

Estimated 1990 Demand	7 MGD
1965 Safe Yield	3 MGD
1990 Deficit	4 MGD

TOTAL ESTIMATED 1990 DEMAND	210 MGD
TOTAL 1965 SAFE YIELD	132 MGD
TOTAL 1990 DEFICIT[1]	78 MGD

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[1] Deficit shown is expected to be met by local resource development.

17. Capability of System to Meet Future Needs

A. Source

The estimated yield from the existing MDC sources of supply is about 300 mgd. In 1971, the average daily demand of all communities serviced by the system was about 322 mgd. At present then, withdrawals from the system exceed the available dependable yield. The most striking example of this demand in excess of supply situation is at Quabbin Reservoir, the main storage facility of the system. From a low pool elevation of 495 feet (full pool 530 feet) the reservoir has been unable to replenish its storage.

Forecast demands on the system for 1990 indicate an additional increment of 141 mgd of yield will be necessary unless water use practices of the serviced population are altered dramatically.

The MDC as a result of their analysis have reported to the Massachusetts State Legislature the next step in providing the supply necessary to meet future needs is the diversion via the Northfield Mountain [1] Project. At a NEWS meeting held in Boston, Massachusetts, in May 1970, local, State and Federal officials agreed that the Northfield Mountain Project was a viable element in any regional water supply plan.

If the yield from Northfield Mountain is made available, the total dependable yield available to the system would be about 372 mgd. Based on the forecast demands, this project would meet supply needs to about 1984. In order to meet the short-range 1990 needs then an additional source of supply will be needed.

In this report, the potential of diverting water from the Millers River Basin, a tributary of the Connecticut, is being investigated. Depending on the method of development employed, this source could produce from 48 to 76 mgd of additional supply.

Development of the Millers River Basin Project as described in this report then could add about 25 percent to the existing system yield. This addition, when combined with the Northfield Mountain yield, would allow adequate supplies within the serviced communities to about 1990.

B. Transmission Facilities

Although the intent of this Interim Report of Survey was to investigate new sources of supply to meet future needs, a preliminary analysis of the MDC's transmission facility was also conducted. The purpose of

[1] Subject of a companion NEWS report.

evaluating the transmission facilities was not to include any needed improvements as recommendations for authorization, but rather to present a full picture of the system's present capability.

In order to determine the adequacy of the major transmission aqueducts, the peak demands for the system had to be estimated. Variations in water demands due to seasonal weather changes have always been important considerations in the design of water supply systems in the northeastern United States and particularly in New England. Historically, summer periods have promoted exceptionally high water demands which quite often last for several weeks. In most cases, these peak demands must be met by the water supply storage reservoirs, since storage within the distribution system itself cannot usually be economically constructed to handle these peak loads.

The ratio of the maximum day demand to the average daily demand is directly related to the type and character of the development within the community or communities to be served. The present MDC system, as described earlier, services 32 member communities within the greater Boston area. Twenty-five of the communities depend wholly upon the system to supply their water needs, while the remaining seven communities make maximum use of their own sources and only rely upon the MDC system to supply their peak demands. The 25 wholly supplied communities range from completely residential in character to the inner core cities with industrial and commercial development. During the recent drought of the 60's, the ratio of the maximum day demand to the average daily demand for the city of Boston reached a high of 1.24, while the ratio for the total 25 communities reached 1.65. This difference has been attributed to the effect of the suburban communities peak demands upon the system. If the MDC is called on to expand its service area, it will be adding suburban communities which are largely residential in nature. Thus, the maximum daily demand ratio can be expected to increase above the present high figure of 1.65. The amount of increase will, of course, depend on what portion of the total water demand upon the system the new members demand represents.

To determine what increase, if any, the transmission facilities would have to supply by 1990, peak demand characteristics of a number of eastern Massachusetts communities were examined. Based on this investigation, it appeared a maximum day ratio of 1.70 to average daily demand represented a reasonable value for planning purposes. A comparison of this figure to other historic and projected maximum day data for large metropolitan systems in the Northeastern United States was then made and proved to be comparable.

Applying the maximum day ratio to demands forecast in the Boston Metropolitan area, it appears the present transmission facilities from Wachusett Reservoir to the Boston City tunnel system may be inadequate. This inadequacy can be primarily attributed to the limiting carrying capacity of the Hultman Aqueduct.

At present, the Metropolitan District Commission has under way a large scale (one million dollar) investigation of its water supply system. Included in this investigation will be an examination of the future courses of action which the MDC may pursue with regard to supply, demand and conveyance facilities. One of the major study elements will be the adequacy of the system's aqueducts. The results of this investigation will describe problem areas and corrective actions needed.

SECTION VII

ALTERNATIVE SOLUTIONS CONSIDERED

18. General

Three alternatives were developed all within the Millers River Basin to meet the water demands of the expanded regional system. The first is diversion directly from the Millers River above Athol to Quabbin Reservoir. This diversion would result in an average annual yield of 68 mgd and would require advanced treatment of the point sources of pollution on the Millers River, upstream of the diversion site. The second alternative calls for a diversion from the East Branch Tully River and from the Millers River above Athol, resulting in an average annual yield of 76 mgd. As in the first alternative, advance waste treatment of the pollution sources would be required; but because Tully Lake would not be used for water supply storage, the reservoir would not have to be stripped. Alternative three is the Tully Complex - a series of small diversion works on four tributaries of the Millers River. An average annual yield of 48 mgd is expected with no treatment required before entering Quabbin Reservoir.

19. Alternative No. 1 - Millers River Diversion

A. General

In this alternative, water would be diverted from the mainstem Millers River above Athol, Massachusetts. An inlet structure on the Millers River, a 10-foot diameter tunnel to Quabbin Reservoir and an outlet structure within the reservoir area would be required. At present, proposed pollution abatement plans by Massachusetts State Agencies include secondary treatment on all point sources of pollution on the Millers and Otter Rivers. However, investigations indicate that additional treatment appears necessary to insure a good water supply source and have been included as elements in this alternative. Plate No. 9 shows the location of the major facilities.

B. Facilities Required

The diversion site would be located on the Millers River about three miles upstream from the confluence of the Tully and Millers Rivers in Athol, Massachusetts. The structure located in Athol would consist of an inlet to the 10 foot diameter tunnel to Quabbin Reservoir controlled by a combination weir-bascule gate extending across the Millers River. The concrete control structure, 120 feet long, would provide a regulated pool for the inlet shaft. The bascule gate, 70 feet long and 5 feet high, would regulate the water height and velocity to the inlet. During diversion, the bascule gate would be raised creating a stilling pond and increasing the water level above the elevation of the inlet structure weir. The 22 foot diameter morning glory inlet tapering to the 10 foot diameter inlet shaft would be located on the northern bank in the center of a 60 foot square chamber cut in rock. The three 8 x 8 foot gates to the inlet chamber would be opened only when diversions were occurring. By regulating these gates in conjunction with the bascule gates, various combinations of diversion flows and downstream flows can be achieved. A plan of the diversion works is shown on Plate No. 10.

Water diverted from the river would enter the morning glory inlet and drop down the 10 foot diameter vertical shaft into the tunnel. The 10 foot diameter tunnel would run a distance of 7 miles from the Millers River inlet to a point south of Gays Hill on Quabbin Reservoir. The tunnel would be excavated in rock by mole methods and lined with concrete to a finished diameter of ten feet. Both the inlet and outlet shafts would be used as construction shafts. The outlet at Quabbin Reservoir as shown on Plate No. 11 would consist of an inclosed transition structure, a concrete stilling basin and a 20 foot wide trapezoidal channel leading to the Middle Branch of the Swift River in Quabbin Reservoir. The structure would be founded on bedrock and includes a wet well with two 8 x 8 foot gated passageways and a control building. The stilling basin would reduce velocities to a reasonable level if Quabbin Reservoir was below elevation 503 msl; but if the pool was higher, discharge would be directly into the pool. The riprapped channel would extend from the stilling basin some 800 feet across a swampy area to the original Middle Branch of the Swift River channel. This channel makes its way to Windsor Dam and the Quabbin-Wachusett tunnel inlet. Table No. 15 summarizes the estimated construction costs for each facility.

C. Waste Treatment Required

An analysis was made of the present and projected loadings of waste discharges upstream from the diversion intake, present and planned

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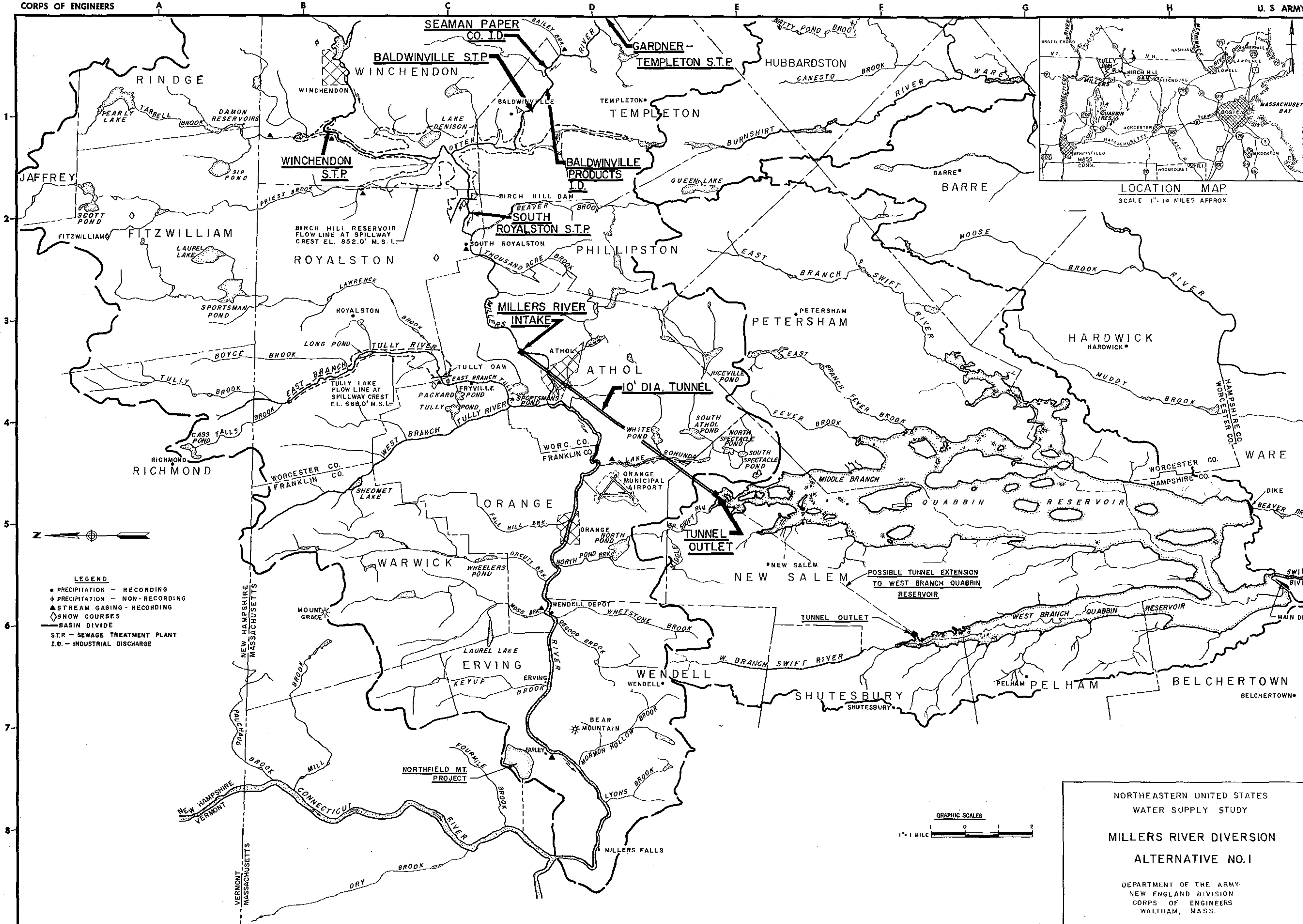
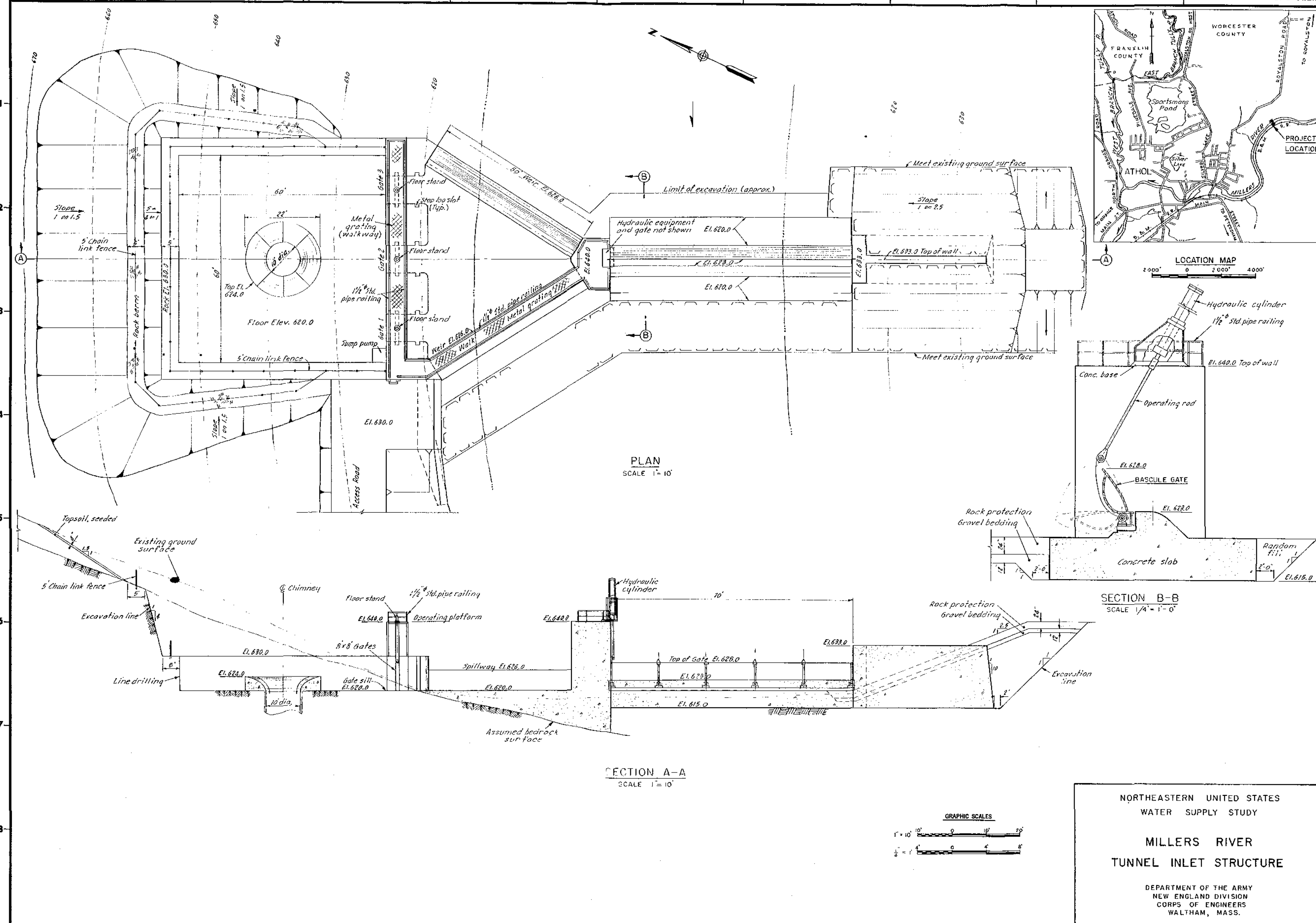


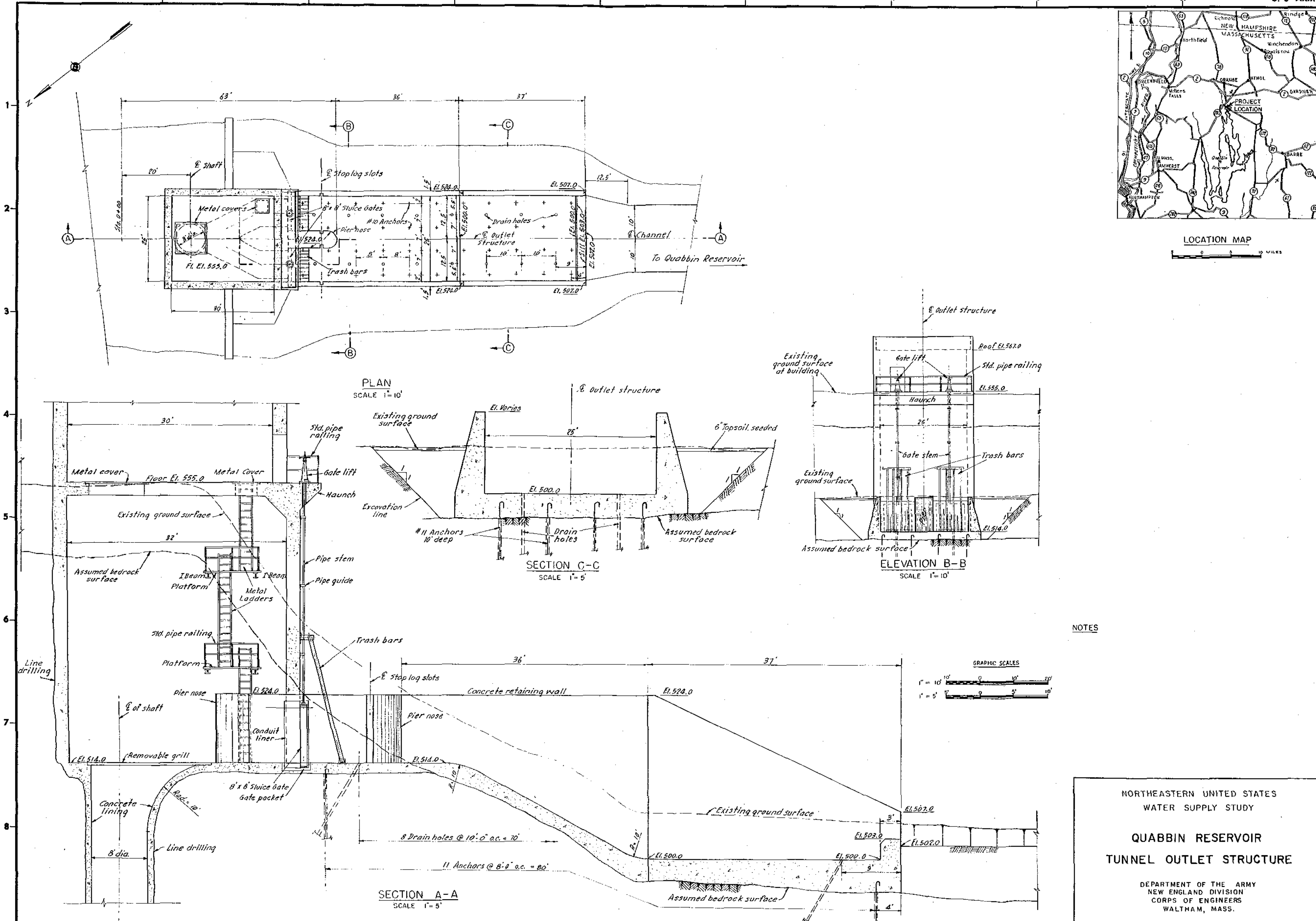
PLATE 9



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

MILLERS RIVER
TUNNEL INLET STRUCTURE

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.



NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

QUABBIN RESERVOIR
TUNNEL OUTLET STRUCTURE

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

treatment, and present and planned waste effluents. Based on available information, further treatment would be required to insure a good quality water for diversion. Our studies indicate that tertiary treatment at the source of pollution is preferred to water treatment at the Millers River intake. The final determination of this additional treatment will be made during the Design Phase. By that time, the planned secondary treatment plants will probably be in operation and the effectiveness of these plants will be known. Also, then the effect the existing sludge banks will have on the water quality can be measured. It is expected that once the load on the river is minimized, the natural flushing action will wash away large amounts of sludge in the Millers and Otter Rivers resulting in a relative stable water quality within a three to five year period.

There are six major sources of pollution upstream of the diversion site. They include two domestic sources, South Royalson and Winchendon, on the Millers River; two domestic, Gardner-Templeton and Baldwinsville; and two industrial polluters, Baldwinsville Products, Inc. and Seaman Paper Company, Inc., on the Otter River.

The planned treatment for the Town of Royalston waste discharge would consist of extended aeration. To the planned secondary treatment, additional facilities required for this alternative would consist of a 100,000 gallon stabilization pond followed by rapid sand filters.

The existing facilities at Winchendon will be upgraded under the State implementation schedule to include aeration and settling tanks as means of secondary treatment. Additional treatment in a .5 mgd which could be required for use of the Millers River as a water supply source would be nitrogen removal followed by rapid sand filtration.

Baldwinsville Products' plant, because of the processes involved in renovating waste paper, uses large quantities of water and returns it to the river as waste discharge. At present, an average effluent flow of 3.5 mgd is discharged to the river untreated. Secondary treatment is planned; but because of the large loadings from the plant, additional treatment beyond the planned process is considered necessary to insure a good quality water for diversion. This 4.25 mgd treatment would be rapid sand filtration followed by granular carbon absorption.

Seaman Paper Company plant is also located on the Otter River, a tributary of the Millers River. At present, waste discharges from the plant average 0.576 mgd and are subject to secondary treatment. Granular carbon absorption would probably be necessary at this plant.

The city of Gardner presently has a secondary treatment facility; but because the waste flow exceeds the design capacity of the plant, desired results are not being obtained. Templeton may also treat their waste at this facility. Construction with a design flow rate of 4.0 mgd is now under way to obtain secondary treatment of the city's waste. However, it appears additional treatment beyond that presently under construction may be necessary. Proposed additional treatment could consist of nitrogen removal followed by carbon absoprtion.

Presently, raw municipal sewage from Baldwinsville is being discharged into the Otter River. Planned treatment to meet the implementation schedule consists of secondary with a design flow of 0.25 mgd. Additional treatment for use of the Millers River as a water supply source could consist of nitrogen removal followed by rapid sand filtration of the final effluent. The total cost of this additional treatment is estimated to be about 8 million dollars, based on cost curves established in the Corps of Engineers Study on the Merrimack River.[1] The annual operating and maintenance cost of this additional work is estimated to be $845,000, based on July 1974 price levels.

D. Operational Procedure

The operation of this diversion would depend first on the flow in the Connecticut River as measured at the U. S. G. S. gaging station at Montague City, Massachusetts, and secondly on the flow in the Millers River at the diversion site. On any given day, the flow in the Connecticut at Montague City would be checked to see if the flow is above 17,000 cfs. If it is not, then no diversion would occur. If it was above the 17,000 cfs, then the flow in the Millers River at the diversion site would be checked. If the flow in the Millers River is less than the flow determined to be required for the river and its environment, hereafter referred to as the control flow, then no diversion would occur. This control flow was determined from flow requirements for; assimilation of wastes; for fish and wildlife and is related to the time of year and the drainage area. The following table shows the control flows at the Millers River intake:

[1] The Merrimack: Designs for a Clean River, a feasibility study prepared by North Atlantic Division, U.S. Army, Corps of Engineers, Sepgember 1971. Northeastern United States Water Supply Study

Table 12
Millers River Control Flow at Intake

	Jan Feb Mar	Apr May Jun	Jul	Aug	Sep Oct Nov	Dec
CSM	0. 5	1. 25	2. 0	1. 0	0. 75	0. 5
CFS	100	250	400	200	150	100

If the Connecticut River flow is above 17,000 cfs and the Millers River flow is above the control flow for that day, then diversions would occur. In no case would water be diverted lowering the flow in the river below the control flow. But neither would the flow be augmented if it was naturally below the control flow. So, the rate of diversion on any given day could vary from zero to the maximum capacity of the tunnel, 730 cfs. Plate No. 12 shows a schematic diagram of the decision process for diversion of Millers River water.

The flow rates in the Connecticut and Millers Rivers would be automatically fed into the control center at the Millers River intake. Also water quality readings would be read from the monitoring station upstream of the diversion site. This information would then be used to determine if the diversion would occur, and if so, at what rate. The bascule gates and the inlet gates would then be raised to allow flow into the tunnel and the gates at the Quabbin outlet would be opened. The entire operation would essentially be operated from the Millers River intake.

E. Project Costs

The total project cost is estimated to be 39 million dollars based on July 1974 price levels. All costs include an allowance for contingencies (20 percent), engineering and design, and supervision and administration. The estimated costs are based on knowledge of the sites and experience on similar projects. Evaluations of property are based on real estate studies and information from local officials, reflecting values in recent sales in the area. A summary of construction costs for diversion and treatment facilities is presented in Table 15.

The average annual costs, also summarized in Table 15, are based on an interest rate of 5-7/8 percent. The project is amortized over a 50 year economic life. Allowances for maintenance, operation and replacement of equipment have been included in the annual charges.

F. Multi-Purpose Applications

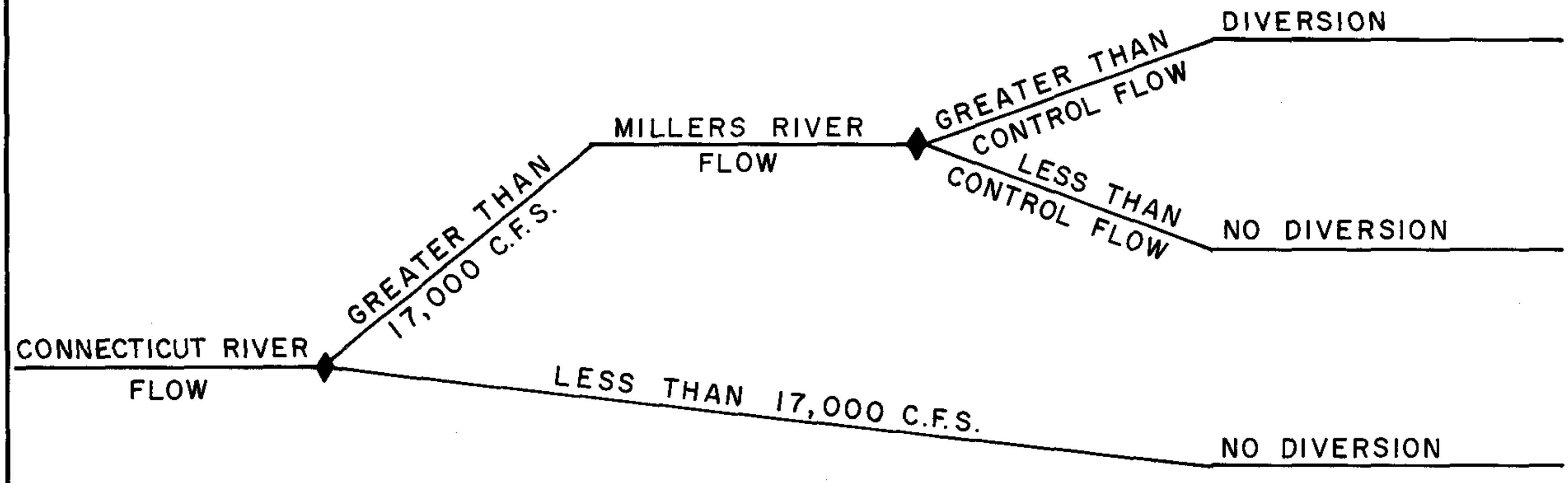
Presently the Otter and Millers Rivers are classified as unsatisfactory, attesting to the fact that the water is unsuitable for most water related activities and uses. However, some twenty-five years ago, the Millers River was considered an excellent trout stream, supporting all types of recreation and wildlife. But with the increase in industrial and domestic discharges, the stream has been rendered nearly void of fish and unsuitable for recreation, including water contact sports. The treatment of the waste discharge required by the state implementation schedule and the proposed advanced treatment for water supply would return the river to its previous excellent state. The river would then offer excellent recreation opportunities as well as an excellent fish and wildlife habitat.

Because diversion would occur during high flow periods, incidental flood control benefits can be attributed to the project. This is due primarily to the fact that higher discharges from Birch Hill Dam would be possible, knowing that 730 cfs would be diverted to Quabbin Reservoir. The control for the maximum amount of discharge from Birch Hill is located in the center of Athol, downstream of the diversion site. With the Millers River diversion operating, an additional 730 cfs can be released downstream before overbank flooding would occur. Also, an additional 730 cfs could be released, instead of stored in Birch Hill Dam, in times of potential flooding, knowing the water will be diverted to Quabbin. However, the dollar value for flood control benefits is minimal because of the high degree of protection on the Millers River provided by Birch Hill and Tully Reservoirs.

The Millers River alternative offers recreation, water quality and flood control opportunities in addition to meeting the water supply needs. Some 30 miles of streams, from Winchendon to Athol on the Millers, and from Gardner to the confluence with the Millers on the Otter River, would become excellent quality water. The water quality of the Millers River below Athol would also be improved because of the reduction in pollutants upstream of Athol. The aesthetic value of the river and environs will be greatly increased.

G. Monitoring Program

The present available data on the water quality and the quality of the bottom deposits are incomplete. Further sampling will be required to design the treatment systems and to determine resultant water quality after treatment of point sources. But after the plants are in operation and the river has stabilized, a permanent monitoring station would be



NORTHEASTERN UNITED STATES
WATER SUPPLY
DECISION DIAGRAM FOR
ALTERNATIVE NO. 1

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 12

required upstream of the diversion site. Measurements would be taken on a number of water quality parameters to insure that the water to be diverted is acceptable.

The water quality of Quabbin Reservoir is also of major importance. So sampling stations would be set up within the Middle Branch of Quabbin Reservoir. Similar tests would be run on these samples, as on the Millers River samples. If discharges are also made into the West Branch of Quabbin Reservoir, then other sampling stations would be set up.

20. Alternative No. 2 - Tully-Millers Diversion

A. General

In this plan, diversion from the Millers River Basin would be accomplished via withdrawals from the East Branch Tully River and the mainstem of the Millers River above Athol, Massachusetts. Facilities necessary for development would include a morning glory type inlet structure just downstream from the existing Tully flood control reservoir and an 8 foot diameter tunnel to the Millers River above Athol. At the Millers River, a second tunnel inlet would be constructed, connected to the Tully aqueduct, and from this location, a 10 foot tunnel would be driven to Quabbin Reservoir where water would be discharged through an outlet structure. As in Alternative No. 1, waste treatment plants on six point sources of pollution would also be required. Plate No. 13 shows the location of the proposed structures.

B. Facilities Required

The Tully diversion site for this alternative is located at the existing Corps of Engineers flood control reservoir on the East Branch Tully River. However, no storage would be used for water supply within the flood control reservoir. The site is located about 4 miles upstream from the confluence of the Tully River and Millers River in Athol. The structure would consist of an inlet to the 8 foot diameter tunnel to the Millers River above Athol and an 8 foot high bascule gate attached to the existing Tully Lake outlet channel.

The existing outlet channel of Tully Lake would be enlarged to 30 feet wide for a distance of 1200 feet. A 30 foot long, eight foot high gate would regulate the water height and velocity in the outlet channel. During diversion, the bascule gate and the three 8 x 8 foot gates would be raised creating a stilling pool and increasing the water level above the lip of the tunnel inlet. The 22-foot morning glory drop inlet would be located adjacent to the outlet channel in the middle of a 60 foot square chamber cut in rock. The three 8 x 8 foot gates to the inlet chamber would be opened only when diversions were occurring. By regulating these four gates and the gates at the existing dam, various combination of diversion flows and downstream flows can be achieved. A plan of these diversion works is shown on Plate No. 14.

Water entering the morning glorty inlet would drop down the vertical eight foot shaft into the tunnel. The eight foot diameter tunnel would be driven a distance of 2. 5 miles from the outlet of Tully Lake to a point upstream of Athol on the mainstem of the Millers River where it would then feed into the Millers-Quabbin leg of the aqueduct. The tunnel would be excavated by mole methods and concrete lined to a finished diameter of eight feet.

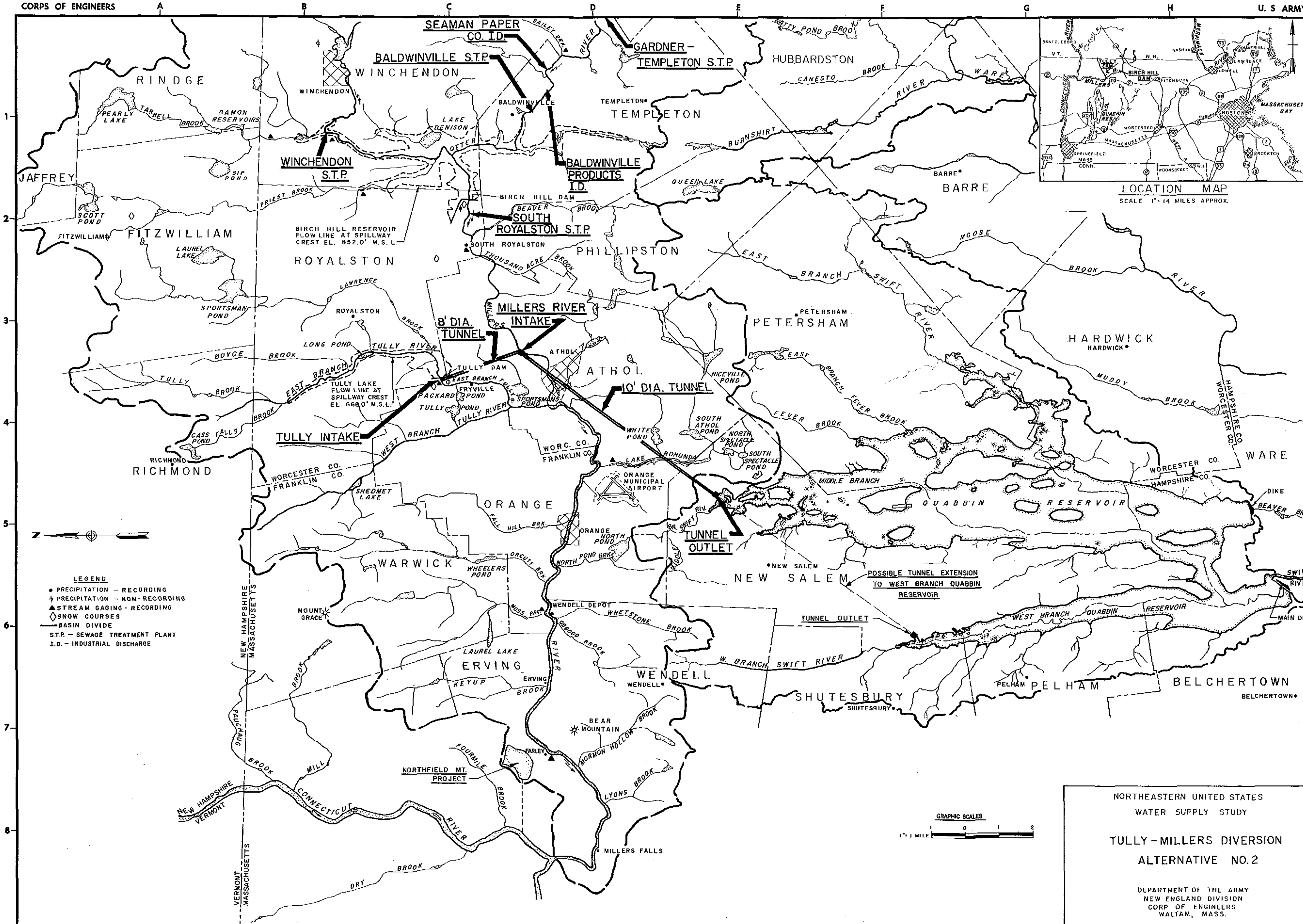
The Millers River diversion site would be in the same location as Alternative No. 1, as shown on Plate No. 9. The facilities would include a weir-bascule structure across the river and a morning glory inlet to the tunnel. A ten-foot diameter tunnel would run from the Millers River intake to an outlet at Quabbin Reservoir. All these facilities would be similar to those required in Alternative No. 1. Descriptions of these works are given in Part B of Paragraph 19 - Alternative No. 1 - Millers River Diversion. Table 16 summarizes the costs for these facilities.

C. Waste Treatment Required

An analysis was made on the present and projected waste loadings upstream of the diversion sites, on the present and planned treatment and on the present and planned waste effluents. Based on available information, the East Branch Tully River water is of good quality requiring no treatment prior to discharge into Quabbin Reservoir. However, as in Alternative No. 1, further treatment of Miller River water is required. Part C of Paragraph 19 details the major sources of pollution and the additional treatment required.

D. Operational Procedure

The operation of this diversion would depend first on the flow in the Connecticut River as measured at the U. S. G. S. gaging station at Montague City, Massachusetts; and secondly, on the flow in the rivers

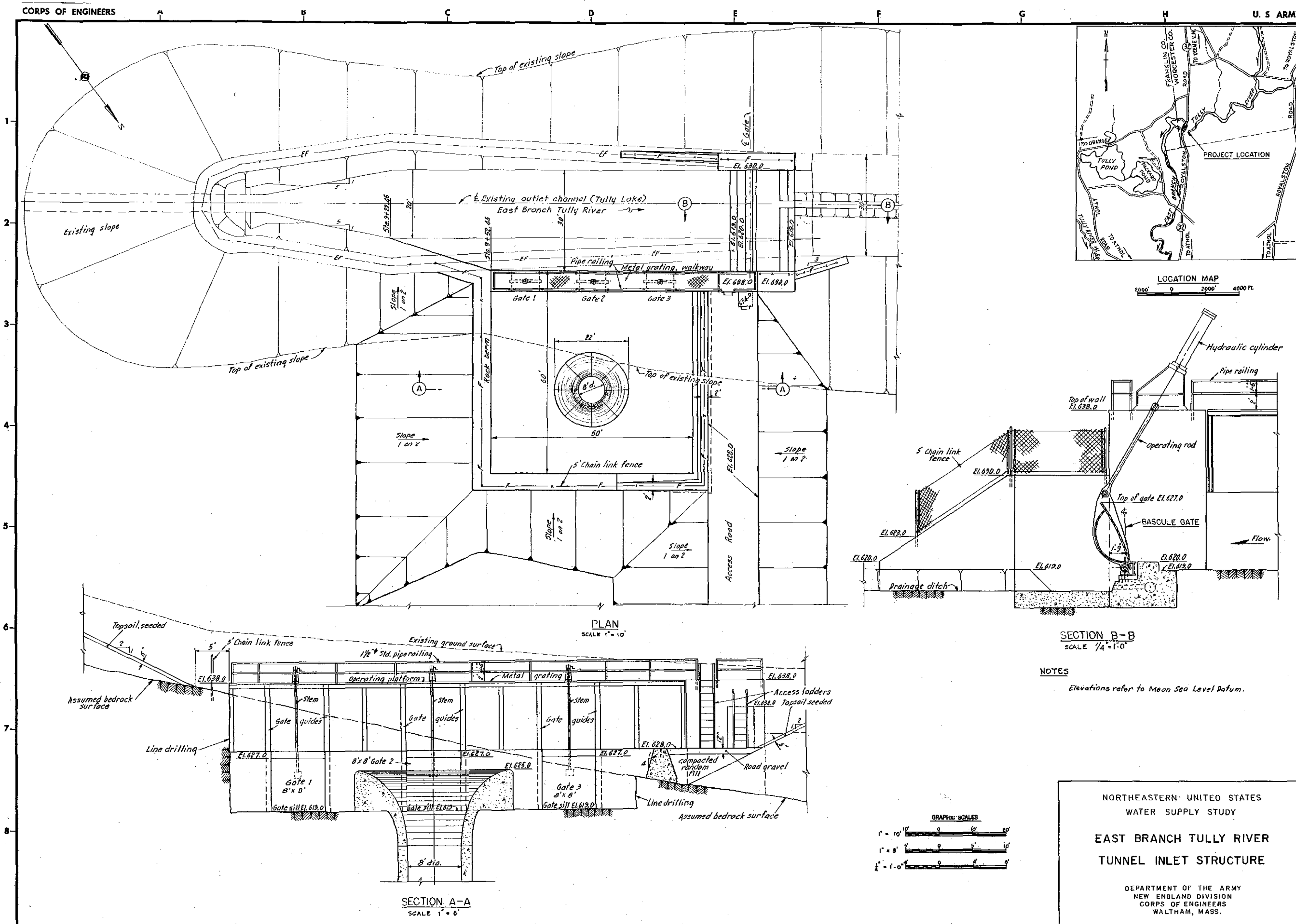


NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

TULLY - MILLERS DIVERSION
ALTERNATIVE NO. 2

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORP OF ENGINEERS
WALTAM, MASS.

PLATE 13



NOTES

Elevations refer to Mean Sea Level Datum.

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

EAST BRANCH TULLY RIVER
TUNNEL INLET STRUCTURE

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 14

at the two diversion sites. On any given day, the flow in the Connecticut River at Montague City would be checked to see if the flow is above 17,000 cfs. If it is not, then no diversion would occur no matter what the flow in the Millers or Tully Rivers is. If the flow in the Millers River at the diversion site is less than the flow determined to be required for the river and its environment, then no diversion from the Millers River would occur. This required flow, referred to as the control flow, was determined from flow requirements for assimilation of wastes; for fish and wildlife, and is related to the time of year and the drainage area. Table 12 shows the control flows at the Millers River intake:

If the Connecticut River flow is above 17,000 cfs and the Millers River flow is above the control flow for that day, then diversion from the Millers River would occur. In no case would water be diverted lowering the flow in the river below the control flow. But, neither would the flow be augmented when it was naturally below the control flow. So, the rate of diversion on any given day could vary from zero to the maximum capacity of the tunnel, 730 cfs.

The same procedure would apply for diversion of East Branch Tully River water, except the control flows and the maximum diversion rate would be less. The control flows at the East Branch Tully River intake are as follows:

Table 13
E. Branch Tully River Control Flow at Intake

	Jan Feb Mar	Apr May Jun	Jul	Aug	Sep Oct Nov	Dec
CSM	0.5	1.25	2.0	1.0	0.75	0.5
CFS	25	63	100	50	38	25

If the Connecticut River is above 17,000 cfs and the East Branch Tully flow is above the control flow for that given day, then diversion from the East Branch Tully River would occur. The rate of diversion on any given day could vary from near zero to 490 cfs, the maximum capacity of the tunnel. Plate No. 15 shows a schematic diagram of the decision process for diversion of Tully and Millers River water.

The flow rates in the Connecticut, Millers and East Branch Tully Rivers would be automatically fed into the control centers at the Tully and Millers River intakes. Also, water quality readings would be read from the monitoring station one-half mile upstream of the Millers River diversion site and samples in the Tully River. This information would then be used to determine if the diversions would occur and if so, at what rates. Diversions might occur at both sites simultaneously or possibly only at one site depending on the river flows. The bascule gates and inlet gates at each diversion site would be regulated in such a manner as to divert the maximum total amount of water to Quabbin Reservoir. The entire operation would essentially be controlled from the Millers River intake.

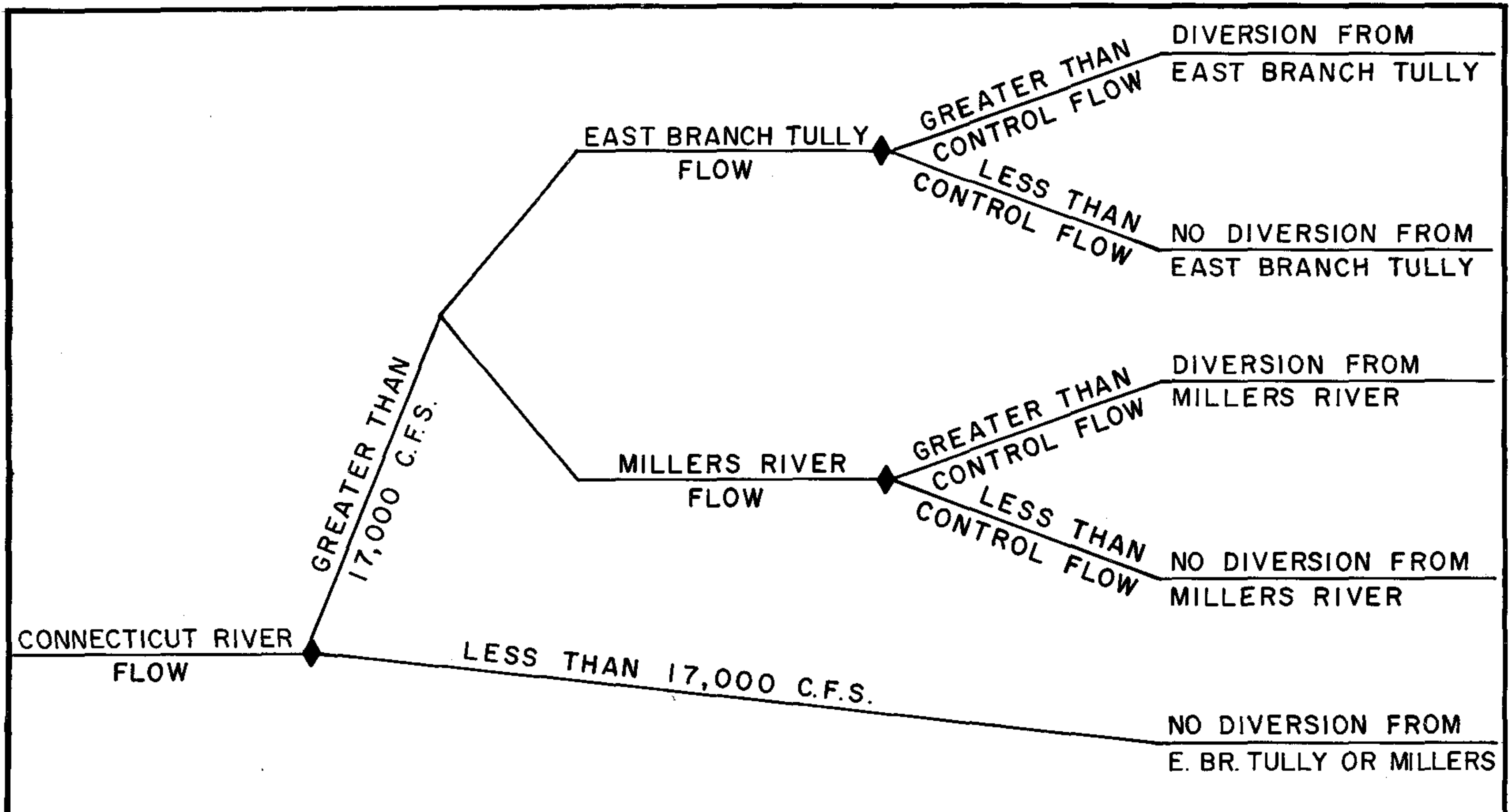
E. Project Costs

The total project cost is estimated to be 49 million dollars based on July 1974 price levels. All costs include an allowance for contingencies, engineering and design, and supervision and administration. The estimated costs are based on knowledge of the site and experience on similar projects. Evaluations of property are based on real estate studies and information from local officials reflecting values in recent sales in the area. A summary of construction costs for diversion and treatment facilities is presented in Table 16.

The average annual costs, also summarized in Table 16, are based on an interest rate of 5-7/8 percent. The project is amortized over a 50 year economic life. Allowances for maintenance, operation and replacement of equipment have been included in the annual charges.

F. Multi-Purpose Applications

Multi-purpose applications of this alternative would be similar to the Millers River alternative. The Millers River would be returned to its previous excellent quality offering numerous recreation opportunities. Additional incidental flood control benefits would occur because higher discharges from Tully Dam would be possible, knowng that a maximum of 490 cfs would be diverted to Quabbin Reservoir. However, this would reduce the amount of water diverted from the Millers River because the maximum capacity of the 10 foot section of tunnel is 730 cfs. During times of potential flooding, coordination would be maintained between Tully and Birch Hill Dams and the two diversion sites to insure the proper operation for flood control. Still, the economic benefits for flood control protection attributable to this alternative are minimal.



NORTHEASTERN UNITED STATES
WATER SUPPLY

DECISION DIAGRAM FOR
ALTERNATIVE NO. 2

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

The existing "Master Plan for Reservoir Development" of Tully Dam could remain essentially the same. The plan consists of the development of a day-use park area including swimming facilities, Doanes Falls scenic area, an overnight camping area, a canoe and hiking reserve and a primitive picnic and hiking area. The only changes from the 1965 Master Plan would be the redesign of the sanitary facilities to meet the Massachusetts Department of Public Health standards for water supply streams. Also, no diversions from Tully would occur during the recreation season. This would insure the protection of Quabbin Reservoir. With these changes, the seasonal use of Tully Lake for recreation would be developed according to the Master Plan.

The Tully-Millers alternative offers the same recreation and water quality opportunities as the Millers River alternative, but also provides flood control protection on the East Branch Tully River. Some 30 miles of streams would become excellent quality, increasing the aesthetic value of the river and associated land.

G. Monitoring Program

On the East Branch Tully River, no further testing on a scheduled basis would be required. Samples would be taken on an intermittent basis (four or five times during the diversion period). If anything showed up in these samples, then a sanitary survey would be performed to isolate the problem.

On the Millers River, the monitoring and sampling programs would be the same as for the Millers River alternative. A monitoring station would be established upstream of the diversion site and samples would be taken on a year round basis. This program will provide ample protection against pollution reaching Quabbin Reservoir, and provide a valuable index of the Millers River water quality for protecting the river quality.

Similar sampling stations as in Alternative No. 1 would be set up in Quabbin Reservoir.

21. Alternative No. 3 - Tully Complex Diversion

A. General

This water supply plan for diversions from the Millers River Basin involves the construction of an 8-foot diameter tunnel from Tully Lake to

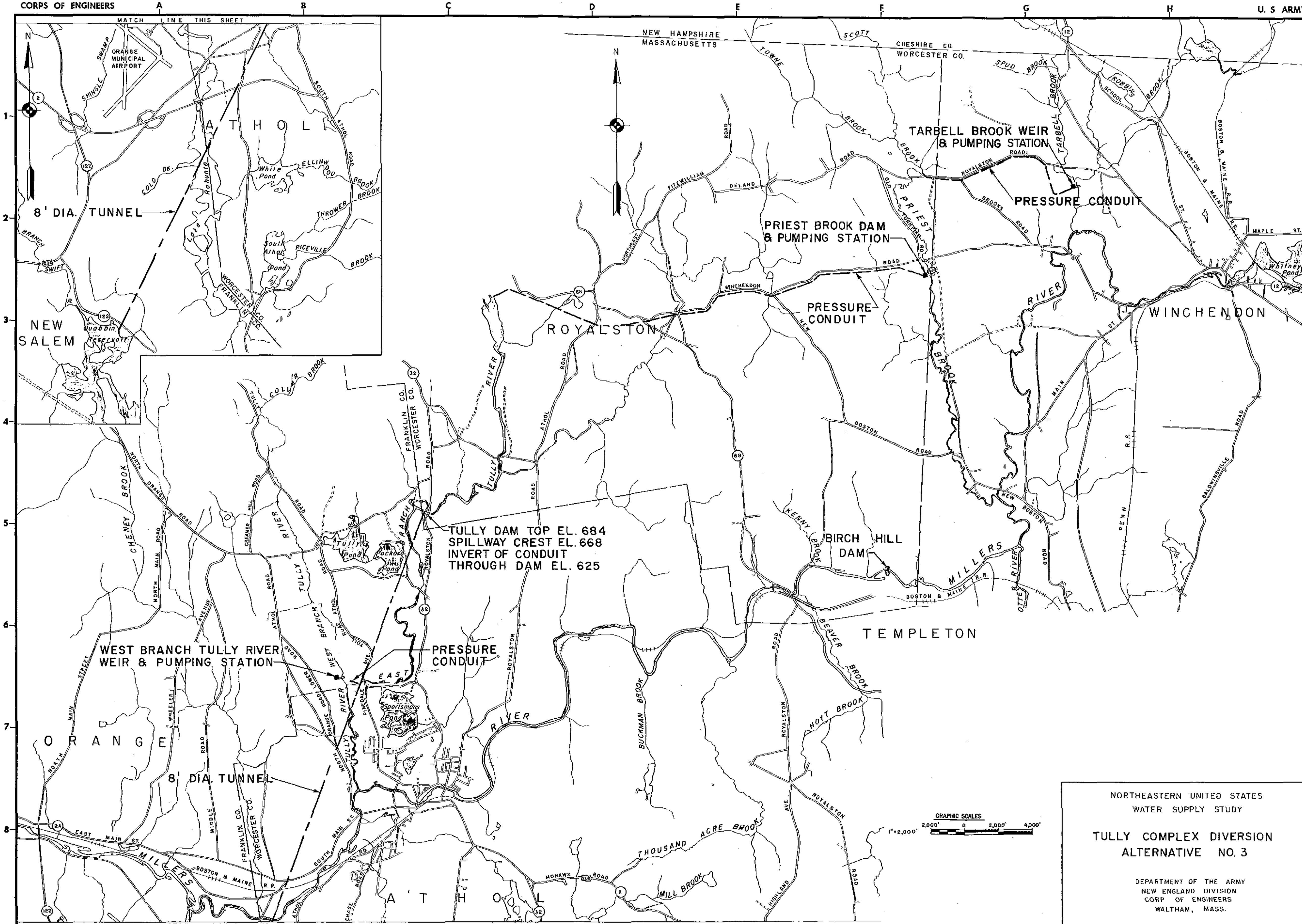
Quabbin Reservoir, a dam on Priest Brook, and diversion structures on Tarbell Brook and West Branch Tully River. Water would be diverted in a pressure conduit from Tarbell Brook to the proposed Priest Brook ponding area. Pumping facilities at the Priest Brook Dam convey this water together with Priest Brook water to Tully Lake. A gravity feed tunnel would then divert these two brook's water plus the East Branch Tully water out of the basin to Quabbin Reservoir. Water from the West Branch Tully could then be pumped into the tunnel near the confluence of the East and West Branches of the Tully River. Recreation and wildlife management programs are also included at these diversion sites. Plate No. 16 shows the location of the proposed structures.

B. Facilities Required

The Tarbell Brook diversion site is located in Winchendon, Massachusetts, about one-half mile upstream of the confluence of Tarbell Brook with the Millers River. The structure consists of a 75 foot long weir and pumping station. A 28 acre pool with a maximum depth of nine feet would be formed by the weir with a top elevation of 840 msl. The inundated area would be cleared and grubbed to improve its appearance. Water would be drawn from the pool and pumped through a 42" diameter pressure conduit running beside Royalston Road to the Priest Brook ponding area. The punps and pipeline would be designed to carry a maximum of 90 cfs. A plan of the facilities is shown on Plate No. 17.

The Priest Brook Dam is located on the Winchendon-Royalston town line, just south of Winchendon Road, some 2-3/4 miles upstream from the confluence of Priest Brook with the Millers River. The pool at spillway crest would have a surface area of 400 acres and a maximum depth of 30 feet. The inundated area downstream of Royalson Road has to be stripped or covered with a gravel blanket to prevent degradation of the water. A weir located upstream of Royalston Road would form a 40 acre wildlife pool. Regulation of this pool would occur during the summer and fall to maintain a shallow depth of water (approximately 5 feet). The 45 foot high main dam buffers the river flow and as such the pool is intermittently filled and emptied inundating the permanent wildlife weir. Plate No. 18 shows the general plan of the dam and reservoir.

A pumping station located at the outlet would divert up to 120 cfs through a 72-inch pressure conduit to Tully Lake. The pressure conduit will run west beside Winchendon Road until it intersects a power line running northwest. Then the conduit follows this easement to Long Pond on the East Branch Tully River.

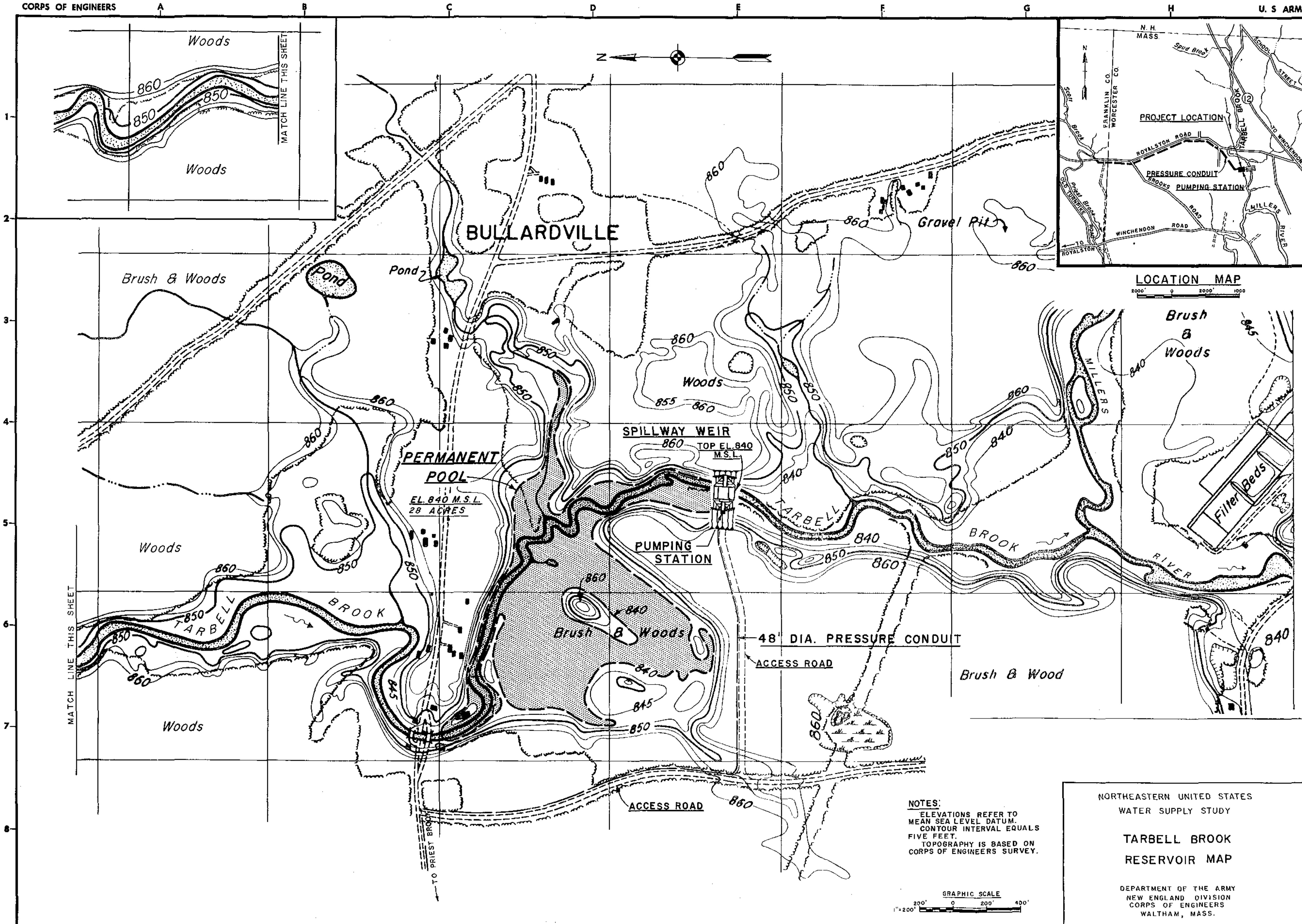


NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

TULLY COMPLEX DIVERSION
ALTERNATIVE NO. 3

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORP OF ENGINEERS
WALTHAM, MASS.

PLATE 16



NOTES:
ELEVATIONS REFER TO MEAN SEA LEVEL DATUM.
CONTOUR INTERVAL EQUALS FIVE FEET.
TOPOGRAPHY IS BASED ON CORPS OF ENGINEERS SURVEY.

NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY

TARBELL BROOK
RESERVOIR MAP

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

CORPS OF ENGINEERS U. S. ARMY

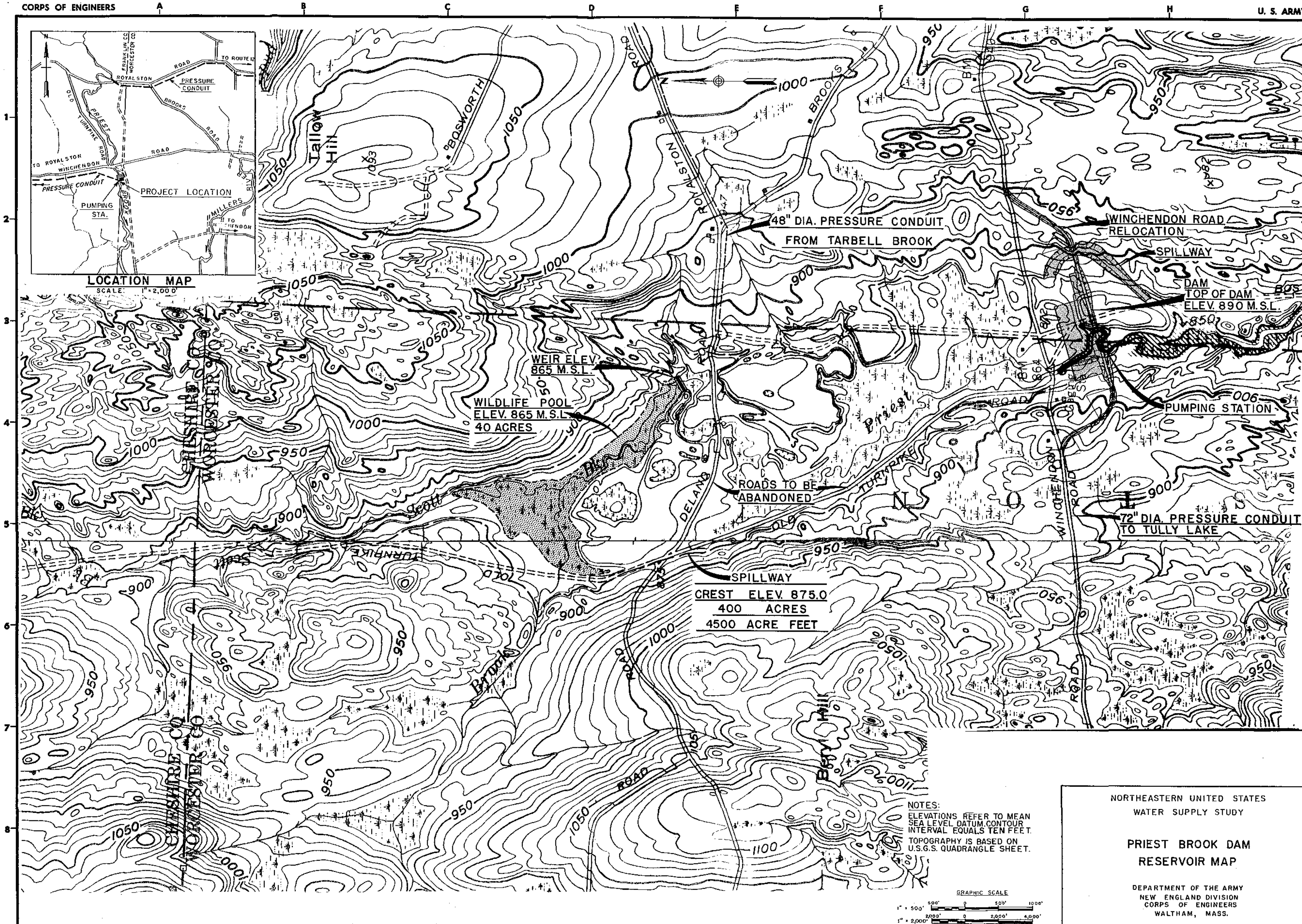


PLATE 18

The diversion site on the East Branch Tully River is located at the outlet of the existing Corps of Engineers Tully Flood Control Reservoir. The existing outlet channel would be enlarged and a morning glory intake structure and a 7 foot high modified bascule gate added. A plan of the limits of Tully Lake and the proposed improvements are shown on Plate No. 19. Only two inches of the 8.3 inches of run-off storage in Tully would be utilized for reregulating flows for diversion to Quabbin Reservoir. During the summer a recreation pool would be held at elevation 648 msl and no diversions from Tully would occur. In order to improve the water quality, the 620 acres inundated would be cleared, grubbed and stripped. Water diverted would enter the morning glory inlet and drop down the vertical eight-foot diameter shaft into the tunnel. The eight-foot diameter tunnel would run horizontally at elevation 300 msl for some 2.2 miles to the entrance shaft from the West Branch Tully River diversion.

The West Branch Tully River diversion site is located about 800 feet upstream of the confluence of the East and West Branch Tully River. The structure consists of a 320 foot long, 25 foot high earth filled dam with a 50 foot wide spillway, a water intake chamber and a pumping station. A permanent 13 acre pool would be formed by the dam to divert from and for wildlife habitat. A maximum of 90 cfs wojld be pumped from this pool to the intake shaft through a 30-inch diameter pressure conduit. Plate No. 20 shows the diversion structure, pipeline and inundated area.

The water entering the eight-foot diameter tunnel would join with the flow from Tully Lake running in an 8.6 mile, eight foot diameter tunnel from the outlet of Tully Lake to a point south of Gay's Hill on Quabbin Reservoir. Plate No. 16 shows the tunnel alignment. The tunnel would have a maximum capacity of 390 cfs.

The tunnel outlet, as shown on Plate No. 11, would consist of an inclosed transition structure, a concrete stilling basin and a twenty foot wide trapezoidal channel leading to the Middle Branch of the Swift River in Quabbin Reservoir. The stilling basin would reduce velocities to a reasonable level if Quabbin Reservoir was below elevation 503 msl; but if the pool was higher, discharge would be directly into the pool. Costs for these facilities are given in Table 17.

C. Water or Waste Treatment Required

The water quality studies conducted prior to 1971 on the Tully Complex streams were limited basically to summer analysis for pollution abatement. These studies were augmented by our own to determine the water quality of the streams.

The physical and chemical analysis of these waters revealed that no treatment would be required prior to the entrance of this water into Quabbin Reservoir near Gay's Hill. The storage time and dilution provided within Quabbin would result in a good quality water. These streams have a natural color to them from the many swamps within the watershed. Otherwise, the streams would be of excellent quality. This water will not have environmental or public health stress on Quabbin Reservoir; and therefore, does not require either waste or water treatment before entering the reservoir.

D. Operational Procedure

As in the other two alternatives, the operation of this diversion would depend first on the flow in the Connecticut River. If the flow in the Connecticut at Montague City is above 17,000 cfs, then the flows at each diversion site would be checked. If the flow at each site is less than the flow determined to be required for the river and its environment, then no diversion would occur. This control flow was determined from flow requirements for assimilation of wastes; for fish and wildlife; and is related to time of year and the drainage area. The following table shows the control flows at the individual diversion sites:

Table 14
Tully Complex Diversion Control Flow at Intakes

	Jan Feb Mar	Apr May Jun	Jul	Aug	Sep Oct Nov	Dec
CSM	0.5	1.25	2.0	1.0	0.75	0.5
CFS						
Tarbell	12.8	32.0	51.2	25.6	19.2	12.8
Priest	9.7	24.3	38.8	19.4	14.6	9.7
E. Br. Tully	25.2	63.0	100.8	50.4	37.8	25.2
W. Br. Tully	9.3	23.3	37.2	18.6	25.2	9.3

1 Data included in Appendix I

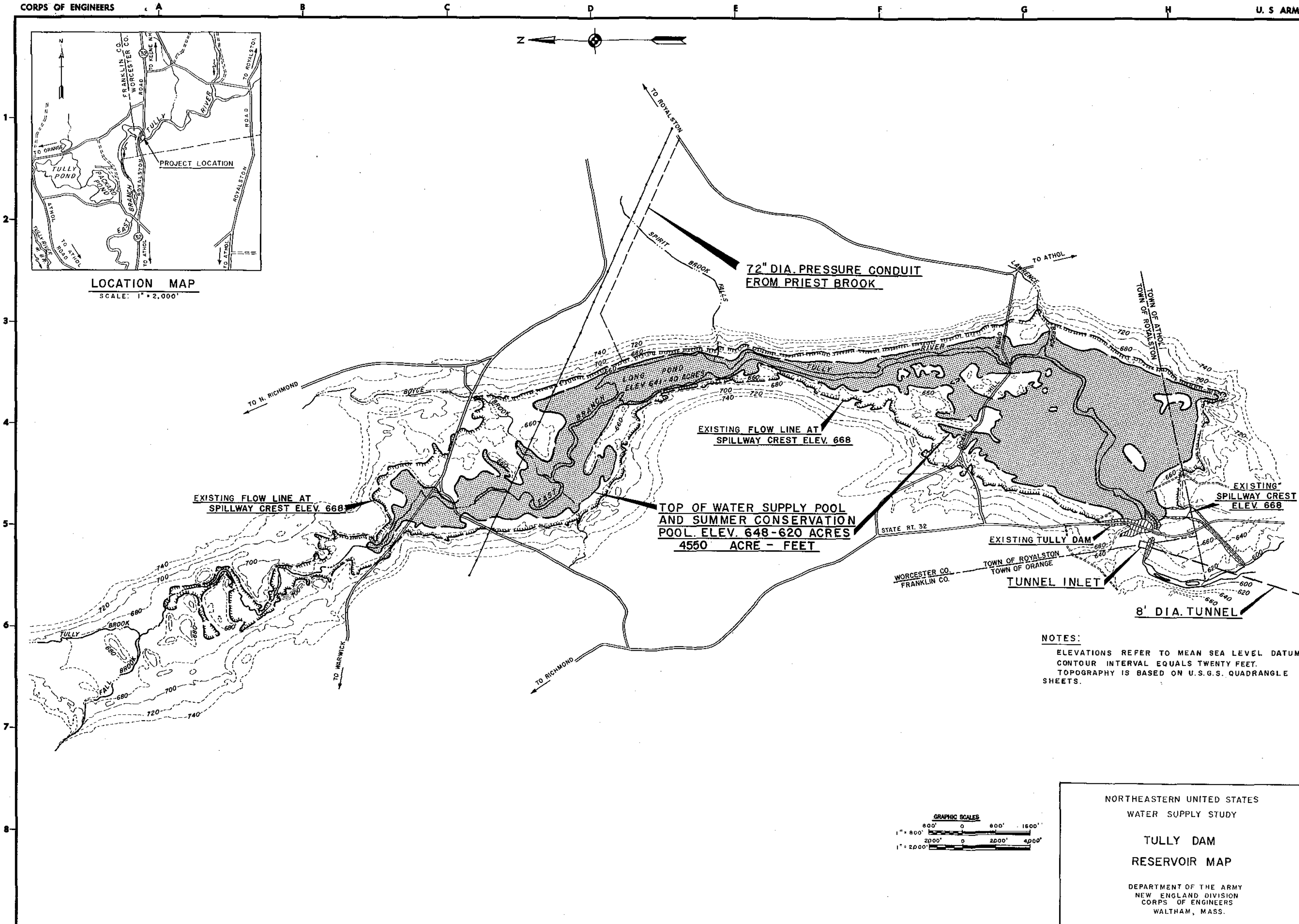

CORPS OF ENGINEERS
U. S ARMY
LOCATION MAP
SCALE: 1" = 2,000'
PROJECT LOCATION
TULLY POND
72" DIA. PRESSURE CONDUIT FROM PRIEST BROOK
TO ROYALSTON
SPIRIT BROOK
TO ATHOL
LONG POND ELEV. 641-40 ACRES
TULLY RIVER
EAST BRANCH
BOYCE BROOK
TO N. RICHMOND
EXISTING FLOW LINE AT SPILLWAY CREST ELEV. 668
TOP OF WATER SUPPLY POOL AND SUMMER CONSERVATION POOL. ELEV. 648-620 ACRES 4550 ACRE - FEET
STATE RT. 32
EXISTING SPILLWAY CREST ELEV. 668
EXISTING TULLY DAM
TOWN OF ATHOL
TOWN OF ROYALSTON
TOWN OF ORANGE
WORCESTER CO.
FRANKLIN CO.
TUNNEL INLET
8' DIA. TUNNEL
TULLY BROOK
FALL BROOK
TO WARWICK
TO RICHMOND
NOTES:
ELEVATIONS REFER TO MEAN SEA LEVEL DATUM.
CONTOUR INTERVAL EQUALS TWENTY FEET.
TOPOGRAPHY IS BASED ON U.S.G.S. QUADRANGLE SHEETS.
GRAPHIC SCALES
NORTHEASTERN UNITED STATES
WATER SUPPLY STUDY
TULLY DAM
RESERVOIR MAP
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 19

CORPS OF ENGINEERS U. S ARMY

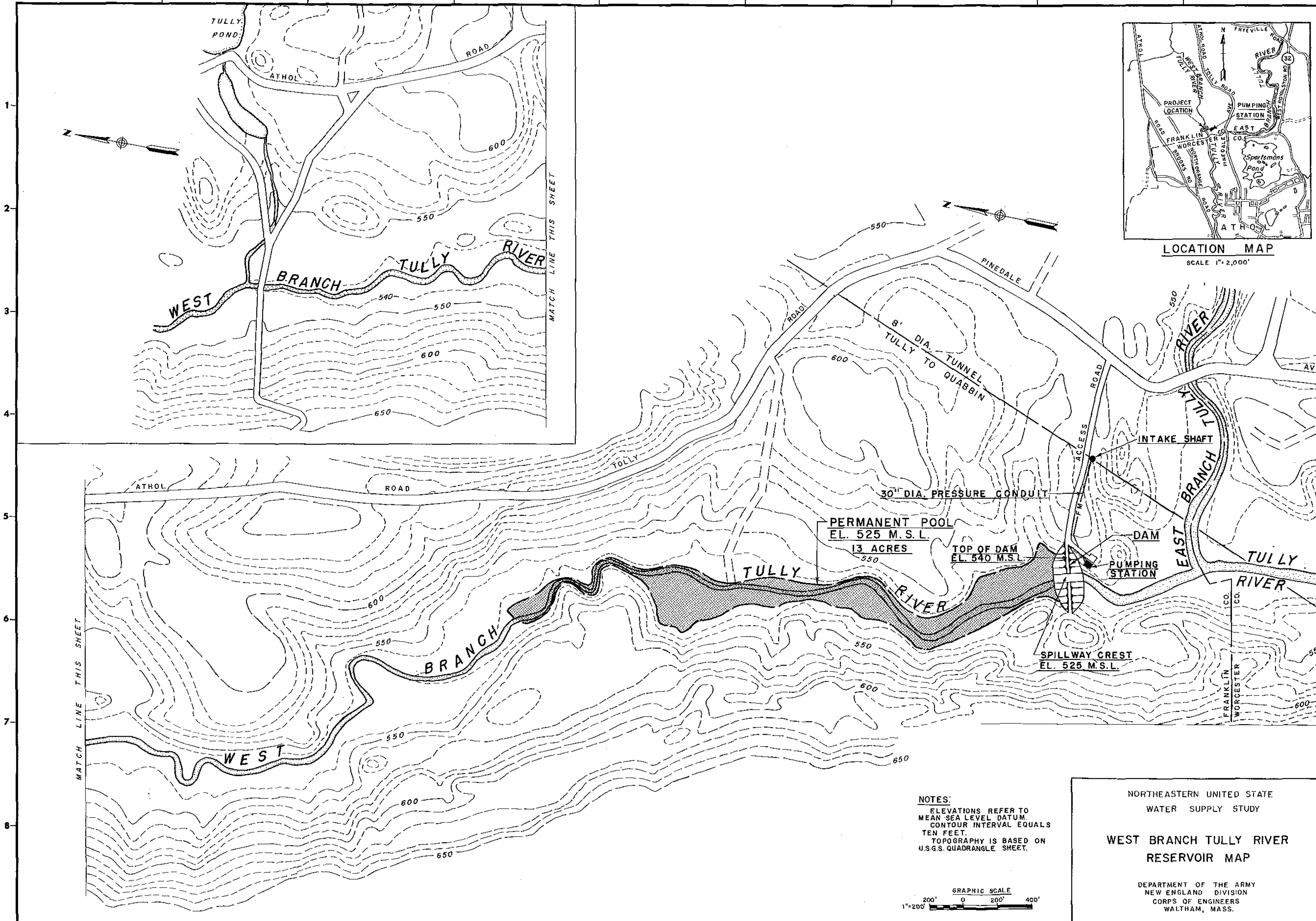


PLATE 20

If the Connecticut River flow is above 17,000 cfs and the flow in the specific diversion site is above the control flow for that day, then diversion would occur from that one diversion site. In no case would water be diverted lowering the stream flow below the control flow, but neither would the flow be augmented if the natural flow is below the control flow. It is possible that diversions might occur from one site but not another.

Plate No. 21 shows a schematic diagram of the decision process for diversions from Tarbell and Priest Brooks and from the East and West Branches of the Tully River.

E. Project Costs

The total estimated project first cost is 49 million dollars based on July 1974 price levels. A summary of construction costs for the diversion facilities is presented in Table 17. These costs include an allowance for contingencies, engineering and design, and supervision and administration. The estimates are based on knowledge of the sites and experience on similar projects. Evaluations of property are based on real estate studies and information from local officials, reflecting values of recent sales in the area.

The average annual costs, summarized in Table 17 are based on an interest rate of 5-7/8 percent. The project is amortized over a 50-year economic life. Allowances for maintenance, operation and replacement of equipment have been included in the annual charges.

F. Multi-Purpose Applications

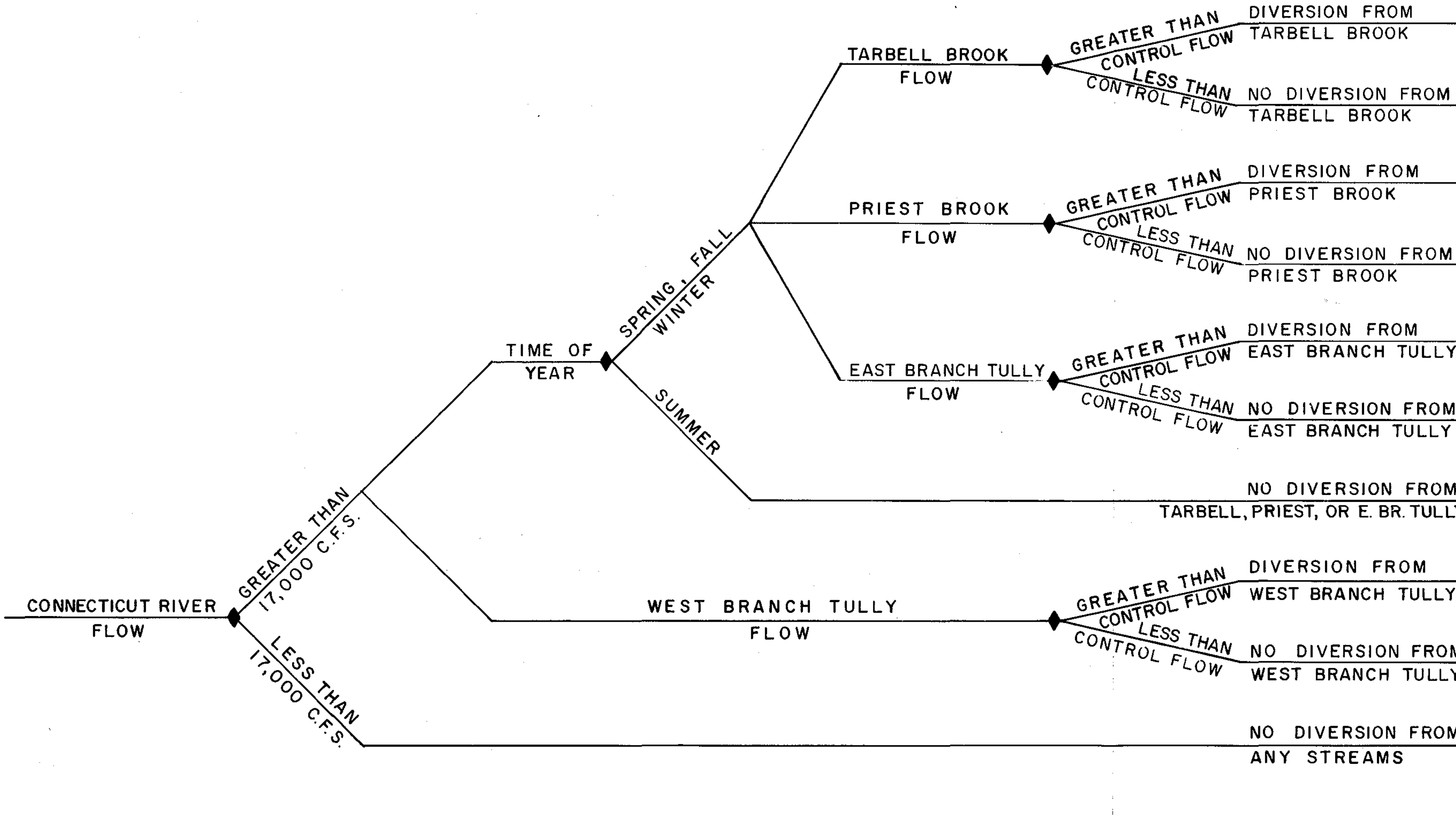
This alternative, in addition to providing water for the Boston Metropolitan Area, offers recreation, flood control and wildlife enhancement benefits. The flood control benefits are essentially incidental to this alternative. This is due to the high degree of protection provided by Tully and Birch Hill Reservoirs. However, since about 380 cfs would be diverted out of the basin to Quabbin Reservoir, less storage would be used within Birch Hill or Tully in times of potential flooding. The dollar value attached to this additional storage is minimal because of the small remaining flood control benefits.

Recreation opportunities will be provided at Tully Lake and Priest Brook Dam. The existing "Master Plan of Reservoir Development" for Tully Dam related to a summer recreation pool at elevation 641 feet msl would be revised to reflect the two inches of runoff storage (elevation 648 feet msl) utilized for water supply. The plan would consist of the development of a day-use park area including swimming facilities, Doane Falls scenic area, an overnight camping area, a canoe and hiking reserve and a primitive picnic and hiking area as did the 1965 Master Plan. The facilities would be adjusted to conform to the new 620 acre pool and the Massachusetts Department of Public Health standards for water supply streams. No diversions for water supply would occur during the recreation season to protect Quabbin Reservoir. The annual recreation benefits for Tully will probably remain in a comparable range to those given in the existing Master Plan ($200,000 to $250,000) even with a revised recreation development plan based on the new pool elevation of 640 feet msl. At the Priest site, most of the recreational use would come from local residents and consist of activities such as snowmobiling, cross country skiing, hiking, nature study and sightseeing. Monetary benefits for these activities are small because of the operating procedure for water supply. The pool would be kept at its lowest possible level at all times. Water would be stored temporarily until it could be transferred to Tully Lake. Therefore, during the low flow summer months, usually there would not be a pool behind Priest Brook Dam. Other recreation sites in the area such as the Otter River State Park or Tully Lake would be more appealing for recreation uses.

Small pools would be created behind the Tarbell Brook and West Branch Tully River diversion works. This shallow lake type environment created would have some value for waterfowl and since the pool at West Branch Tully would be long and narrow, some trout fishery would also be provided there especially during the spring and early summer. On Priest Brook, a small pool will be held upstream of Deland Road for waterfowl. During the summer and fall, the main pool probably would be empty so the waterfowl pool could be operated. This would provide a habitat for migratory birds. Wildlife benefits, however, are incidental to these projects. If it was found during design that the entire Priest Brook Reservoir area has to be stripped and grubbed for water quality, then the waterfowl pool would be useless because it wouldn't attract waterfowl. At West Branch and Tarbell sites, the pools would normally be held full even without waterfowl benefits.

G. Monitoring Program

On the four streams, no further testing on an intensive basis would be required. Samples taken during this study indicate a constant good quality water from these streams. Therefore, during diversions, samples would be taken on an intermittent basis. If anything changed in the stream's characteristics, a sanitary survey would be performed to determine the cause of the change. Sampling stations would also be set up within the Middle Branch of Quabbin Reservoir. This program would provide a valuable tool in analyzing the effect of the diversion on Quabbin Reservoir.



NORTHEASTERN UNITED STATES WATER SUPPLY

DECISION DIAGRAM FOR ALTERNATIVE NO. 3

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.

PLATE 21

SECTION VIII

ESTIMATES OF FIRST COSTS AND ANNUAL CHARGES

22. First Costs

A. General

The total estimated costs for the three Millers River alternatives are given in Tables 15, 16 and 17. Estimates were based on preliminary designs providing safe structures for given conditions plus 20 percent contingencies. All costs are based on July 1974 price levels. Costs of engineering and design, and supervision and administration are estimated on percentages of the total construction cost.

B. Waste Treatment

The pollution treatment costs include all of the costs necessary to construct advance waste treatment facilities for water supply. These treatment facilities would be in addition to those required by the state implementation schedule. Costs were established using the data developed in the Corps of Engineers Study entitled, The Merrimack: Designs for a Clean River, and updated to July 1974. Appendix D details these costs on a plant by plant basis.

C. Tunnel Estimates

Estimates of construction costs for the various tunnels were prepared utilizing a computerized tunnelling program, assuming a mechanical rock tunnelling (MOLE) method of construction. All costs were based on the input of the assumed geologic conditions which controlled design functions, with labor, equipment and material rates for the area, including a 5 percent profit and a 25 percent overhead margin. Geologic data was derived from existing literature and mapping. Alignments were made on a straight-line minimum distance basis. The cost indices for labor, equipment and materials are based on Engineering News Record (ENR) values for the month of July 1974. Material disposal costs were computed on an area basis at a circumferential distance from the most appropriate shaft. The land cost for disposal which is included in the tunnel costs represents a real estate estimate of the land values for the area involved. Detail tunnel costs are given in Appendix D and E. Also, they further explain the basis for these estimates.

D. Structural Features Costs

The structural features include such things as intake and outlet structures and for Alternative No. 3, dams, weirs, transmission facilities, and reservoir clearing. Quantities of the principal construction items were estimated on the basis of a preliminary design which would provide a safe structure for given conditions and hydraulic criteria. Unit prices are based on average bid prices adjusted to July 1974 levels for similar work in the New England area. In determining the safe designs topographic maps of the U. S. Geological Survey, as well as previous Corps of Engineers surveys, were supplemented with centerline profiles of the dam sites. Geologic reconnaissance of each site was made. At the Priest Brook dam site, these investigations were augmented by previous subsurface explorations.

In Alternative No. 3, the inundated area in Tully Lake and Priest Brook would be cleared, grubbed and stripped to insure good water quality. The cost of removal was based on a unit price for the estimated quantities together with the real estate acquisition and haul costs for disposal. Appendix D gives the pertinent details of the structural features and the cost estimates on a quantity by quantity basis.

E. Real Estate Costs

All the costs necessary to purchase the required land or to obtain easements across private owned land are included in this item. The value of the lands and improvements within the project area were based on comparable sales data obtained from knowledgeable real estate people in the area. In addition, estimates were made for relocation expenses, possible litigation expenses, severance damages, and administrative costs necessary for acquisition. A contingency allowance of 20 percent is considered reasonable to provide for refinements in taking lines or ownerships, for adverse condemnation awards and to allow for actual negotiations.

Cost of easements required for the construction of the tunnels were estimated on a cost per tract basis. Included are costs for surveys, legal descriptions, title evidence, appraisals, negotiations and other administrative matters relating to acquiring easements. Also, a contingency allowance of 20 percent was added to cover actual negotiation. Detailed estimates of real estate costs are given in Appendix F - Real Estate Studies.

F. Interest During Construction

This is the additional investment necessary to construct the project. It is assumed that the construction period would be three years with equal construction costs per year. Interest during construction was estimated by multiplying the 5.875 percent interest rate by one-half the estimated construction period times the total project first cost.

23. Annual Charges

Average annual costs summarized in Tables 15-17 are based on interest rates of 5.875 percent for Federal and non-Federal costs. Investment costs for the project are amortized over a 50-year economic life.

Annual charges for the operation and maintenance include a cost estimate of the men, chemicals and other items necessary to operate the waste treatment facilities necessary for the water supply project. Also, the operation and maintenance costs associated with the inlets, outlets and tunnels were estimated.

Major replacement is the amount of money required annually at a 5.875 interest rate which will purchase equipment that only has a useful life of 25 years. Included in this item is the replacement of the advanced waste treatment equipment, such as pumps, valves and certain dispensing equipment.

TABLE 15

SUMMARY OF FIRST COSTS AND ANNUAL CHARGES

ALTERNATIVE NO. 1 - MILLERS RIVER DIVERSION

(July 1974 Price Level)

PROJECT FIRST COSTS

POLLUTION TREATMENT	$ 9, 843,000
MILLERS RIVER INTAKE	952,000
10' DIAMETER TUNNEL (MOLE)	27,648,000
QUABBIN OUTLET	440,000
REAL ESTATE COSTS	473,000
TOTAL PROJECT FIRST COST	$ 39,356,000
INTEREST DURING CONSTRUCTION	3,468,000
INVESTMENT	$ 42,824,000

ANNUAL CHARGES

INTEREST AND AMORTIZATION	$ 2,670,000
OPERATION AND MAINTENANCE	873,000
MAJOR REPLACEMENT	146,000
TOTAL ANNUAL CHARGES	$ 3,689,000

TABLE 16

SUMMARY OF FIRST COSTS AND ANNUAL CHARGES

ALTERNATIVE NO. 2 - TULLY - MILLERS DIVERSION

(July 1974 Price Level)

PROJECT FIRST COSTS

POLLUTION TREATMENT	$ 9,843,000
TULLY INTAKE	450,000
MILLERS INTAKE	952,000
8' x 10' DIAMETER TUNNEL (MOLE)	36,933,000
QUABBIN OUTLET	440,000
REAL ESTATE COSTS	530,000
TOTAL PROJECT FIRST COST	$49,148,000
INTEREST DURING CONSTRUCTION	4,331,000
INVESTMENT	$53,479,000

ANNUAL CHARGES

INTEREST AND AMORTIZATION	$ 3,334,000
OPERATION AND MAINTENANCE	881,000
MAJOR REPLACEMENT	146,000
TOTAL ANNUAL CHARGES	$ 4,361,000

TABLE 17

SUMMARY OF FIRST COSTS AND ANNUAL CHARGES

ALTERNATIVE NO. 3 - TULLY COMPLEX DIVERSION

(July 1974 Price Level)

PROJECT FIRST COSTS

TARBELL BROOK	$ 3,329,000
PRIEST BROOK	$ 12,869,000
EAST BRANCH TULLY	2,211,000
WEST BRANCH TULLY	1,574,000
QUABBIN OUTLET	440,000
TOTAL DIVERSION FACILITIES	$ 20,423,000
TULLY LAKE TO QUABBIN RESERVOIR 8' DIAMETER TUNNEL	28,538,000
REAL ESTATE EASEMENTS	285,000
TOTAL PROJECT FIRST COST	$ 49,246,000
INTEREST DURING CONSTRUCTION	4,340,000
INVESTMENT	$ 53,586,000

ANNUAL CHARGES

INTEREST AND AMORTIZATION	$ 3,341,000
ELECTRICAL CHARGES	146,000
OPERATION AND MAINTENANCE	53,000
TOTAL ANNUAL CHARGES	$ 3,540,000

SECTION IX

PROJECT IMPACT ANALYSIS

24. General

A. Background

This section of the report will deal with an evaluation of the social impacts which the construction of the proposed water supply project would have. The objectives are to determine and evaluate the potential beneficial contributions as well as neutral or adverse effects which the project's development may have. These effects are evaluated in both the source and service area. Impacts are quantified and translated into dollar values where possible. In areas where impacts are not quantifiable, the effects of diversion are discussed so that the reader will be aware of all the ramifications of implementing the projects. Every effort has been made to consider all significant effects of the proposed diversion, for even the more subtle changes to a stabilized community can have important and long lasting implications.

A data baseline was first established so that changes which would occur without the proposed diversion could be measured. The baseline data in the short term are merely extrapolations of existing trends. For example, it has been assumed that in-and-out migration patterns will continue, that no major economic shifts will occur and that existing regulatory policies and jurisdictional lines will remain unchanged. Beyond the short term projections, anticipated development became less clear. Social expectations tempered by judgmental decisions have produced as reasonable projections as possible. Specifically, population, water use, and development expectations were taken from available master plans of cities and towns affected. Where no such data were available, projections of economic activity were estimated.

Impacts directly from constructing the project were based on engineering plans and site maps. To relate construction activities to impact categories, estimates were made of labor demands and capital expenditures as well as the physical alterations to specific sites relating to human activity.

In evaluating the projects, guidelines given in Senate Document 97 were followed. In addition, the proposed Water Resources Council guidelines [1] were followed and benefits as well as losses were evaluated on a three account system. The guidelines were established under the premise that the over-all purpose of water and land re-planning is to reflect society's preference for attainment of the three objectives defined as:

1) To Enhance the National Economic Development by increasing the value of the nation's output of goods and services and improving the national economic efficiency.

2) To Enhance Environmental Quality by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems.

3) To Enhance Regional Development through increases in a region's income; increases in employment; distribution of population within and among regions; improvements in the region's economic base, and educational, cultural, and recreational opportunities; and enhancement of its environment and other specified components of regional development.

A complete accounting of relevant beneficial and adverse effects are presented as they relate to the above social objectives.

Beneficial and adverse effects are measured in monetary terms for the national economic development objective and the regional income component of the regional development objective and for some social factors.

Other beneficial or adverse effects are measured in non-monetary terms for components of the environmental quality, for the non-income components of the regional development objective, and for most social factors. Estimating these beneficial and adverse effects is undertaken in order to measure net changes with respect to particular objectives that are generated by the project. The beneficial and adverse effects on social factors are also displayed in the system of accounts.

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[1] Federal Register, Volume 36, No. 245, Part II, Water Resources Council - Proposed Principles and Standards for Planning Water and Related Land Resources.

Thus, there are beneficial and adverse effects for national economic development, environmental quality, and regional development objectives and beneficial and adverse effects on social factors. These are measured in quantitative units or qualitative terms appropriate to a particular effect.

The multi-objectives are not mutually exclusive with respect to beneficial or adverse effects, and decisions as to the selection of the recommended plan have been made by considering the difference in the effects of the alternative plans.

B. Parameters Used in the Benefit/Cost Analysis

1) Discount Rate - A discount rate of 5-7/8 percent was used throughout the computations. This is a rate furnished by the United States Office of Management and Budget. The rate reflects the average price being paid for money borrowed by the government.

Impacts were estimated on a year by year basis into the future. The capital dollar values were brought back to year 0 using present worth single payment factors to get a capital dollar value at year 0. These capital dollar values at year 0 were then amortized over the life of the project to put them into annual dollar values.

2) Project Life - A 50-year project life was selected as best fitting the circumstances of type of projects under consideration. Although the projects under consideration will not meet Eastern Massachusetts' needs 50 years into the future, it is expected that they will remain operative and be contributing to the system at least up to 50 years in the future. Consideration was given to using a somewhat longer project life, but such a course of action would contribute little for three reasons. First, projections of population and water consumption become extremely uncertain when carried into so distant a future. These projections are a basis for loss and benefit computations. As a matter of fact, loss totals enjoying a high degree of confidence end about 1990. Second, future technology, an unknown quantity, may very well make new sources of water supply competitive with the system as we now know it. Third, calculations beyond 50 years yield very little in the way of dollar amounts when figures are brought back to present worth. For instance, a $1.00 value at year 51 is worth only $0.06 when brought back to year 0. The $1.00 at year 100 is worth only $0.004 when brought back to year 0.

The year 1976 was selected as the year in which the project could possibly go into operation. This is year 0 in the 50-year economic life.

3) Price Level - The price level established for this study was based on the prevailing prices in 1974. No changes in this price level were considered during the life of the project. This assumption, although not supportive by historical record, should not lead to any erroneous conclusions because, in general, the rate of price level increases in the past has tended to be uniform among the various facets of the economy. There is no reason to suspect that the rate of price level change in the donor area, receiver area, or New England region would vary significantly from the national average.

Benefits and adverse effects of the project have been determined by comparing the conditions expected with the plan to the conditions expected without the plan. In other words, impacts are defined as deviations from the no-project baseline. The term "no-go situation" in the following paragraphs is defined as the state of affairs which will prevail if the existing water supply system is not augmented with additional water from any source. The "go situation" conversely is the situation which will exist if the particular alternative in question is implemented. The no-go situation, therefore, becomes a baseline for comparison of the various alternatives.

C. Elements Included in Analysis

1) General - A contract was negotiated with a private concern to make a study and report on the social and economic impacts of diverting water from the Millers and Connecticut River Basins into the Eastern Massachusetts water supply system. The report[1] which evolved from this study is included in this report as Appendix K. This work, which can best be described as a case study, first established the existing socio-economic framework in which the proposed water supply development will be acting. After establishing this baseline situation, the contractor then determined the positive and adverse effects which could be expected if the water supply developments were to be constructed.

Budgeting and time constraints on the study made it impossible to do a complete economics analysis under contract. The contract was negotiated midway through the NEWS Study and final alternative plans had not been decided upon; in fact, results of the study could have changed the direction of the investigation. With this in mind, it was decided that the money

[1] Identification and Assessment of Social and Economic Impacts of the Connecticut and Millers River Basin Diversions - Abt Associates, Inc., June 1972.

spent under contract would be used to the best advantage if an intensive study were made on the Northfield Mountain Project and on one specific alternative on the Millers River Basin. The contract work was then used as the basis of in-house study of further alternatives and evaluations under the other two accounts. Regional Development was selected as the account to be addressed by the study.

This approach worked out very well. Impacts on the receiver area depend primarily on the quantity and timing of deliveries to the system. It makes little difference where the water comes from. If the study had taken a drastic change of direction and some different source of water emerged as a better alternative, the contract work would have been a valuable reference; because although values would change, the methodology would be no less valid.

2) Economic Loss Categories - Economic losses estimated in this report as a result of supply shortage may be described either as one time events or happenings on an annual basis. In the former category belong all losses connected with investment projects undertaken to either permanently increase the supply of water available to an area or to permanently decrease the consumption rate. Once such investment projects are undertaken, the losses that formerly resulted will not be experienced again unless the shortage grows more severe. Altogether, seven types of concrete losses were analyzed in this study. The Contractor gathered information in the field and made numerous telephone inquiries. He also relied heavily on collected data and methodologies developed under a study for Resources for the Future, Inc.[1]

LOSS TYPE 1

Annual Loss Categories: Industrial Sector.

Two major subheadings fall in this category:

(1) Business losses resulting from forced slowdowns or shutdowns in production due to drought; and

(2) Disparate costs, like dry-hole wells, cloud seeding, and water conservation programs. The magnitude of these losses was

[1] Drought and Water Supply, Russell et al, Johns Hopkins Press, Copyright 1970.

estimated first at lost value added for shutdowns and forced slowdowns, and then as the costs of the various "other" projects.

LOSS TYPE 2

Annual Loss Categories: Municipal Sector.

The subheadings distinguished here include:

(1) Lost Revenue on water not sold (the prevailing price of water times the shortage computed as the difference between potential demand and available supply);

(2) Emergency Supply Costs, based on interviews with water systems managers and press accounts;

(3) Other, the "costs of redistributing the town's available water in a desired pattern as in hiring spray trucks to cart river water to thirsty trees and shrubs," and certain investment projects which ought to be classified as permanent losses; for example, the costs of "a well for a town swimming pool . . . . . efforts to find new groundwater sources, etc." For the purpose of this study, the "Municipal Other" category is treated as an annual cost because it has been impossible to split apart this category into its appropriate investment and annual components.

(4) Tree Losses, these losses reflect the town's inability to water trees as a result of shortage.

LOSS TYPE 3

Annual Loss Categories: Revenues Lost to Municipal Sector.

Included here were the losses of municipal revenue on water that the town was not able to sell because of the restrictions. Markup margins on water purchased from the Metropolitan District Commission (MDC) were estimated on the basis of a telephone survey of the sample town's water departments. Not included here are the revenues lost by the MDC system itself; this category includes only the markup lost by the client municipalities.

LOSS TYPE 4

Annual Loss Categories: Commercial Sector.

As in the industrial sector losses include:

(1) Business Losses, and

(2) Projects aimed at reducing consumption. This section consists of non-manufacturing establishments, including firms engaged in trade and services.

LOSS TYPE 5

Annual Loss Categories: Domestic Sector.

The only subheading falling in this category consists of sprinkling losses, the losses of consumer surplus resulting from a complete or partial ban on lawn sprinkling.

LOSS TYPE 6

Permanent Losses: Industrial Sector.

The only heading here reflects the claimed costs of all permanent water-use adjustments . . . . . (such as) cooling towers for the recirculation of cooling water; wells drilled to increase the plant's independent supply capability; process-water recirculation systems; additions to existing dams; new dams; installations of air-cooled window air-conditioners, and others.

LOSS TYPE 7

Permanent Losses: Domestic Sector.

Like industries, certain households made emergency investments in order to shield themselves from the effects of drought. There appears to have been no domestic investments undertaken to control consumption (i. e., recycling), and investments which were undertaken to provide new, independent sources of water appear not to have been profitable. This implies fairly large losses for this sector.

Permanent Losses: Other Sectors.

Investments of varying profitability were undertaken by sectors outside of the industrial and the domestic sectors, however, these investments were quite small. It was felt that they would be best handled as annual impacts.

One aspect of these losses deserves special consideration. Can losses for a number of firms be summed up and expressed as losses for the industrial sector as a whole? For example, in a hypothetical situation where a serious labor shortage exists, losses of value-added in industries forced to restrict operations due to water shortage may be cancelled by gains in value-added by industries which profitably hire the labor released. In this study, it has been assumed that all value-added is lost when a firm is forced to shut down its operations. It is possible to look at the entire system shortage and make a series of alternative assumptions by which people and resources can be transferred either to non-water-dependent production units or to production units outside the shortage area. In this way the system losses can be, in fact, less than the full losses of firms suffering the shortage; therefore, in instances where we are working with estimates of the cost of shortage in the region, no benefits are reaped from stimulation occurring in non-shortage areas or in non-water using activities outside the region as a consequence of the slowdown.

3) Socio-Economic Impact Categories - Impact categories used to measure effect of the project's construction are shown in Table 18. The measures they include, because of lack of data, are in some cases at too fine a level of detail. The categories shown, however, were used to the greatest extent possible in attempting to define socio-economic impacts in both the Connecticut River Basin and the Boston Metropolitan Region.

4) National Economic Development - The National Economic Development (NED) objective is enhanced by increasing the value of the nation's output of goods and services and improving the national economic efficiency. Entries under this account can, of course, be either positive or negative. Any item under this account will be carried under one or both of the other two accounts (Regional Development and/or Environmental Quality). The converse is not true. An example is in order.

Suppose an item, say a paper product, is not manufactured in the region of a proposed project because of a drought situation. This would create a loss in the regional economy. If the lost production were made up elsewhere in the United States, then there would be no loss in the NED account. If, on the other hand, the paper product was a specialty of the region that was effected and could not be manufactured elsewhere, then the loss would

TABLE 18

SOCIO-ECONOMIC IMPACT MEASUREMENT

Impact Categories	Suggested Measures	Units	Time Period
1. Land Use	Net change in the percent distribution of acres devoted to industrial, commercial, agricultural, residential & recreational uses.	Percent	Long
	Net change in land use caused by the various physical diversion facilities (e.g., dams, pipelines, tunnels).	Acres	Short & Long
	Net change in the amount of land available for development.	Acres	Long
2. Population	Net changes in the age, income, race and ethnicity distributions of the local population, particularly in the donor areas.	Percent	Short & Long
3. Municipal Finance	Loss of assessed valuation as a percent of community total.	Percent	Long
	Increase in assessed valuation resulting from improved water service.	Dollars	Long
	Net change (gain/loss) in tax revenue resulting from improved water service.	Dollars	Short & Long
4. Commercial Activity	Net change over normal trends in gross wholesale and retail sales of those facilities affected by availability of water resources.	Dollars	Short & Long
	Net number of businesses located (displaced) by a facility	Number	Short & Long

TABLE 18 (cont'd)

5. Housing	Net change (increase/decrease) in number of housing units by number of bedrooms by price (OR).	Number	Short
	As a percent of community's total stock in the receiver area.	Percent	Short
6. Education	Net change in amount of classroom and other educational space required for projected change in school-age population resulting from in- and out-migration.	Sq. Ft.	Short & Long
	Net changes in cost of teacher and other education staff required for projected change in school-age population resulting from in- and out-migration.	Dollars	Short & Long
	Net change in cost of providing school services because of changes in busing.	Dollars	Short
	Use of facilities for educational programs.	Day/Yr.	Short
7. Leisure Opportunities	Net change in the total number of acres of parks and playgrounds in the Study Area.	Acres Visitor Days	Short & Long
	Net change in the extent to which planned recreation space meets American Society of Planning Officials planning standards relating types of space to population characteristics.	Percent	Short
8. Cultural Opportunities	Total number of churches, historical sites or other cultural institutions taken.	Number	Short
	Cost of relocating churches, historical sites and other cultural institutions, minus compensating payments.	Dollars	Short
	Increase in locational amenities (e.g., improved site planning, additional parking, etc.) as a result of relocation.	No. of Improvements	Short

TABLE 18 (cont'd)

9. Transportation	Net change in travel time as a result of facilities from major residential areas to activity centers: health, commercial, recreation, employment, education, cultural	Min./Trip x Trips/ day	Short
10. Municipal Services	Net change in cost of providing water, sewerage, and garbage service and other municipal services.	Dollars	Short & Long
	Net change in residential insurance rates.	Percent	Long
11. Security	Number of positive and negative statements about the opportunities for system failure, as revealed by a content analysis of local news media.	Number	Short & Long
12. Community Image	Changes in property values adjacent to supply facilities	Dollars	Short & Long
	Number of positive and negative statements about the community as revealed by a content analysis of local news media.	Number	Short & Long
13. Community Cohesiveness	Total number of community, regional, statewide and national groups taking a position (making a public statement) for or against the project.	Number	Short
14. Citizen Involvement	Total number of community, regional, statewide and national groups involved in the planning of the project, times the level of their involvement, according to the following scale of increasing involvement: 1. Attendance at hearing; 2. Citizen opportunity to critique plans at public meetings; 3. periodic workshop planning sessions with community representatives; 4. community advocate planner participated on equal basis with technical staff in all planning activities; 5. appointment of arbitrative hearing officer who makes final decision in case of dispute between community & Army Engineers.	Weighted No.	Short

TABLE 18 (cont'd)

15. Institutional Involvement	Total number of jurisdictions involved in the totality of the construction process for a water supply facility.	Number	Short & Long
	Number of applications submitted to the MDC for water supply service by cities and towns; disposition and frequency of refusal.	Number	Short & Long
16. Economic Stability	Net change in income resulting from construction and related activities.	Dollars	Short & Long
	New increase in private investment.	Dollars	Short & Long
17. Real Income	Net change in per capita income.	Dollars	Short & Long
	Net change in tax assessments.	Dollars	Short & Long
	Net change in regional net income.	Dollars	Short & Long
18. Employment	Number and type of jobs created/lost.	Number	Short & Long
19. Industrial Activity	Change (increase/decrease) in number of industrial establishments.	Number	Short & Long
	Change in productivity indices.	Dollars	Short & Long
20. Agricultural Activity	Change (increase/decrease) in number of farm acres.	Number	Short & Long
	Change in production per acre.	Dollars	Short & Long

occur in the NED account as well as the regional account. Following the logic further, if other manufacturers outside the region were operating to capacity, then they could not take up the lost production. The lost production would not be made up in the United States and the loss would be to the region as well as the NED account. The same logic can be applied to an item which is part of the environmental quality account.

It is quite possible that only a part of a regional or environmental account entry will appear in the NED account. Example, a loss in the region that will be only partially mitigated elsewhere in the country.

In this study, as described earlier, seven economic loss categories were used to determine the economic impact of water shortages. All of these categories express losses to the regional development.

Upon examining the losses in each category, it was decided that losses in four of the categories; Municipal Emergency Supply and Other, Municipal Lost Revenue, Domestic Losses and Domestic Investment would be carried 100% into the NED account. It was decided that the remaining three; Industrial Business Losses and Other, Commercial Losses, and Industrial Investment would net out to zero (mitigated in full by the national economy). Industrial Investments are assumed to operate at no loss; therefore, losses were 0 in both accounts.

Based on the above procedure, then, the method for determining NED losses was to remove Commercial Losses and the Industrial Business Losses and Other from total Regional Economy Losses.

5) Environmental Quality - In assessing the impact of the project on the environment, contractor services as well as in-house personnel were used extensively. An evaluation was made of the project's impact on the Connecticut River Estuary; on the Connecticut and Millers Rivers; on the environment of the receiving water storage reservoir, i.e., Quabbin; and the Boston Metropolitan Region. Full descriptions of these investigations are included later, and in Appendices I and J.

6) Regional Development - In assessing the impacts which the project's implementation might have on regional development, a subdivision into two groupings of communities was required. This subgrouping was necessitated because any impact of the diversion on Connecticut River Basin communities (or source area) would be keyed to

the withdrawal of water from the basin. On the other hand, communities supplied by the water would experience a separate set of impacts from any of the alternatives.

A determination thus was made as to what, in fact, were the supplier and receiver communities sub-groups. It was decided that only the communities directly affected by the project would be considered as suppliers. It became clear that social and economic impacts in the Connecticut Basin would be most significant for site-specific activities. Communities such as Deerfield and Leominster would probably be slightly affected by the project, however, not to a point that could be quantified or even speculated upon reasonably. Greenfield, Erving, Royalston, Warwick, Athol, Winchendon, and Orange are the only communities that would be noticeably affected by projects in the Millers River Basin. Environmental studies presented in this report indicate that downstream communities on the Connecticut River, as well as the Connecticut River estuary, would not be significantly affected from an environmental or ecological standpoint. On this basis, it was decided not to include these communities among the suppliers. A complete listing of all communities examined as potential suppliers is given in Table 19.

Receiver communities are defined as present recipients of the Metropolitan District Commission Water Supply System plus those communities which will have no other reported engineering option than to join the system to meet their 1990 water supply needs. The sixty-six receiver communities are given in Table 20.

25. Evaluation

A. Regional Development Account

1) General

As described earlier, impacts from the implementation of the various alternative projects on the regional development within the study area received considerable attention. Included in this analysis was an assessment of the project to socio-economic impact on communities both within the basin (or suppliers) from which water would be diverted as well as communities which would be supplied by the diverted flow (or receivers).

To impose some rational structure of the impact analysis, the study was structured in a matrix fashion. The alternative projects, i.e., Nos. 1, 2 and 3, together with the baseline "no-go scenario," were considered with respect to each relevant impact category shown in Table 18. By considering the projects in this fashion, an evaluation of each of the projects' economic and social change relative to the no project baseline was possible.

Obviously, not every possible combination is equally important. In some cases, the magnitude of change in a given impact category is so small as to be insignificant. In others, a forecast change may be small but long-lived, thus overshadowing a larger but more ephemeral effect. Generally, the effort was made to distinguish short- and long-term changes for each impact category as it relates to communities. Short-term has been defined as the five-year term required for construction. Thus, impacts so accounted are project-specific. Long-term encompasses changes falling outside that limit and related less to the specific works proposed than to the shortage/availability of a quantity of water equal to that diverted.

If implementation of any of the alternatives was delayed an inordinate period of time, then the impacts as described, of course, became less valid. A delay of ten years, for example, would place communities served by the regional system in a precarious water supply situation.

The total number of communities examined totalled eighty-four. Of this number, eighteen were considered potential suppliers or municipalities from whom water would be diverted. The balance of sixty-six municipalities or communities which would use the water were considered as receivers. A listing of the municipalities included in the supplier and receiver sub-groups is given in Tables 19 and 20.

Insofar as possible, profiles of sample communities were built in the same format as impact categories described in Table 18. Over the short term, baselines are merely a continuation of trends noted in the profiles. For example, it has been assumed that in- and out-migration patterns will continue, that no catastrophic economic shifts will occur and that existing regulatory policies and jurisdictional lines will remain unchanged. Over a time horizon extended to fifty years, however, anticipated development is less clear. However, the study made use of the best projections available. Specifically, population, water use, and development expectations have been taken from the available Master Plans of cities and towns affected. Where no such data were available, projections of economic activity were developed. In all cases, impacts are defined as deviations from the data baseline.

TABLE 19

SUPPLIER COMMUNITIES

Ashburnham	Northfield
Athol	Orange
Deerfield	Petersham
Erving	Phillipston
Gardner	Royalston
Gill	Templeton
Greenfield	Warwick
Hubbardston	Wendell
Montague	Westminster
New Salem	Winchendon

TABLE 20

RECEIVER COMMUNITIES

Fully Served Members

Arlington
Belmont
Boston
Brookline
Chelsea
Everett
Lexington
Lynnfield
Malden
Marblehead
Medford
Melrose
Milton
Nahant
Newton
Norwood
Quincy
Revere
Saugus
Somerville
Stoneham
Swampscott
Waltham
Watertown
Winthrop

Partly Served Members

Cambridge
Canton
Needham
Peabody
Wakefield
Weston
Winchester

Served Non-Members

Clinton
Chicopee
Framingham
Lancaster
Leominster
Marlborough
Northborough
Southborough
South Hadley
Wilbraham

Communities with No Other Option

Ashland
Avon
Bolton
Braintree
Dedham
Dover
Holbrook
Holliston
Hudson
Lincoln
Maynard
Medfield
Millis
Natick
Norfolk
Randolph
Sherborn
Stoughton
Stow
Sudbury
Wellesley
Westwood
Weymouth
Woburn

2) Methodology

Because individual treatment of each of the eighty-four communities (source and receiver) affected by the proposed projects was never considered feasible within the dollar and time constraints of the study, it was necessary to limit the number investigated. Therefore, a computerized clustering exercise was performed which grouped communities according to sixteen descriptors:

(1) Present Population
(2) Projected Population
(3) Population Growth
(4) Population Density
(5) Employment
(6) Median Income
(7) Present Water Demand
(8) Projected Water Demand
(9) Status of M. D. C. Service (served, non-served)
(10) Total Industrial Demand
(11) Restrictions on Consumption (yes, no)
(12) Supplier or Receiver
(13) Future M. D. C. Member
(14) Present M. D. C. Member
(15) Served Non-Member
(16) Have No Opinion

Next, one element from each of the sixteen resulting clusters was chosen for further study. In the subsequent data gathering effort, it became clear that not every sample community had the data required to establish competent socio-economic profiles, or more importantly, Master Plans from which to extract expectations of future development. Supplier towns, with the exception of Greenfield, were particularly data-poor. Indeed, they were omitted from a second clustering program which was then run for only the sixty-six receivers.

It appeared from preliminary work that long-term economic impacts were going to be most important in receiver communities. Therefore, the variables chosen for the second clustering program were restricted to economic factors suggestive of uniform economic structure. The outputs of this second program are as follows:

CLUSTER 1.

<u>Elements:</u> Arlington, Revere*, Saugus, Winthrop, Weymouth

<u>Representative and Descriptors:</u>

Revere*

- Low-income area
- Urban/Boston satellite, North
- Largely residential
- Commercial economy
- Stagnant or little growth potential
- Low water user
- MDC receiver

CLUSTER 2.

<u>Elements:</u> Belmont*, Brookline, Milton, Swampscott, Lincoln, Lexington, Newton, Nahant, Needham, Wellesley

<u>Representative and Descriptors:</u>

Belmont*

- High-income area
- Urban/Boston suburb or satellite
- Residential
- Commercial economy
- Moderate growth rate
- Low water user
- MDC receiver

CLUSTER 3.

<u>Elements:</u> Boston*, Cambridge, Maynard

<u>Representative and Descriptors:</u>

Boston*

- Low-income to poor area
- Urban/city core
- Increasingly less residential
- Mixed economy; larger proportion commercial
- Stagnant to negative growth rate
- High water user
- MDC receiver

CLUSTER 4.

Elements: Chelsea, Everett, Peabody*, Clinton, Chicopee, Ashland, Woburn

Representative and Descriptors:

Peabody*
- Low-income area
- Urban independent/North Shore
- Highly industrial
- Moderate growth rate
- High water user
- MDC receiver (very small % of total consumption)

CLUSTER 5.

Elements: Lynnfield, Marblehead, Weston, Winchester, Southborough, Dover, Holbrook, Medfield*, Stowe, Westwood

Representative and Descriptors:

Medfield*
- Moderate or middle-income area
- Rural/Southwest of Boston
- Largely residential
- Mixed economy; moderately industrial
- Stagnant or low growth potential
- Low water user
- Not an MDC receiver

CLUSTER 6.

Elements: Malden, Medford*, Somerville, Stoneham, Lancaster, Watertown

Representative and Descriptors:

Medford*
- Moderate or middle-income area
- Urban/Boston satellite or suburb
- Residential
- Economy mostly commercial
- Stagnant or low growth potential
- High Water user
- MDC receiver

CLUSTER 7.

Elements: Melrose, Marlborough, Wilbraham, Holliston, Hudson, Randolph*, South Hadley, Millis, Stoughton

Representative and Descriptors:

Randolph*

- Moderate to middle-income
- Urban independent/South of Boston
- Moderately residential
- Mixed economy - highly industrial
- High growth potential
- Low water user
- Not an MDC receiver

CLUSTER 8.

Elements: Wakefield, Norwood, Framingham, Natick*, Leominster

Representative and Descriptors:

Natick*

- High-income area
- Urban independent/West of Boston
- Moderately residential
- Mixed economy - highly industrial
- Moderate growth potential
- High water user
- Not an MDC receiver

CLUSTER 9

Elements: Canton, Avon, Bolton, Sherborn, Sudbury, Northborough*, Norfolk

Representative and Descriptors:

Northborough*

- Moderate or middle-income area
- Rural/West of Boston
- Largely residential
- Mixed economy - mostly industrial
- High growth potential
- Moderate water user
- MDC receiver

CLUSTER 10.

Elements: Quincy, Waltham, Braintree*, Dedham

Representative and Descriptors:

Braintree*
- High-income area
- Urban/South of Boston
- Moderately residential
- Industrial economy
- High growth potential
- Moderate water user
- Not an MDC receiver

The subgroup of supplier communities selected for close examination were limited to seven: Greenfield, Erving, Royalston, Warwick, Athol, Winchendon, and Orange. These municipalities were chosen because early in the investigation it became clear that social and economic impacts in the Connecticut Basin would be most significant for site-specific activities, remote suppliers like Deerfield and Leominster were eliminated. Though a case could be made for examining towns downstream on the Connecticut, it was felt that the environmental studies under way would point out any important changes for these communities. From the social and economic standpoint, analysis by community outside the immediate diversion area would not have been fruitful, or even possible.

The backbone of the analysis was the projection of economic and residential activity for the receiver area from 1970 to 2020. Of the sixty-six communities total, none but a very few had themselves done any significant forecasting.

As noted above, the basic strategy was to build clusters on the basis of key economic indicators. In this way, information could be used in our analysis that could not have been obtained for all sixty-six cities in a reasonable time. While most work actually proceeded on the 66-city level, values for certain variables were estimated for cluster sample cities only and then assumed to apply also to other communities in the same cluster. Thus, when a variable could not be feasibly collected for all receivers, an estimate was made for a representative city in each cluster and assumed that its value was shared by all other members of its cluster.

Even so, information was not easy to come by, especially for the very distant years, 1990 - 2020. As is usually the case for projective studies, some very general numbers were available for the far end of the time horizon; projections prepared for New England, or at best for eastern Massachusetts. The application of such general information to particular localities has been a risky venture, however sensitively done.

Thus, the implication is that estimates presented later are likely to be far more meaningful for larger groups of jurisdictions studied (i. e., for clusters, or for the aggregate of all receivers) than for any one cluster element. This is especially true for the years near the 2020 time horizon. Accordingly, loss estimates are not presented for each individual receiver since such displays of data would be likely to contain very large errors. In a cluster, on the other hand, errors are likely to cancel, and the results for the cluster as a whole are likely to be far more reliable.

Finally, to fill out impact categories related to project - specific changes, use was made of historical data from two case study communities. In the supplier area, the Town of Northfield and its responses to a very much larger construction project at Northfield Mountain (Northeast Utilities) was used as an upper bound on similar types of changes anticipated for the alternative projects. In the receiver area, interview data provided by the Chairman of the Planning Board in Stoughton established the dimensions of change to be expected in the event of widespread water shortages resulting from a situation caused without a project being implemented. This community is generally conceded to be the most deprived of potential M. D. C. water customers and offers a good example - though admittedly over a very brief period compared to the fifty-year life attempted here - of the trends to be expected in other communities equally deprived by a failure to provide for projected demands.

In the course of data collection, some contact, direct or by telephone, was established with all seventeen sample cities and towns. In most cases, specific water-related agencies or elected officials were successfully sought out.

Conversations about the major issues of the water supply problem in metropolitan Boston and diversion plans were held with residents of both supplier and receiver areas; roughly ten in each area, half being sidewalk encounters and the others more structured interviews with private individuals known to have an interest in the project. In addition, five planning officials were approached as spokesmen for their respective constituencies in eastern and western Massachusetts. Four were members of local Planning Boards and one headed a county planning office. Other noteworthy sources included: 1. Northeast Utilities, 2. Maine Yankee, 3. The Metropolitan Area Planning Council, and 4. The Commonwealth's Office of Regional Affairs (Department of Community Affairs), Department of Education (Research and Development), Department of Natural Resources (Division of Water Resources, Division of Water Pollution Control), Department of Public Works, Division of Employment Security (Research Department), and Department of Public Health.

3) Impact on Supplier Area

The impact categories shown in Table 21 present forecasted changes in the supplier communities. The data shown represent total impacts for the sum of individual towns actually affected. Qualitative data which is keyed by superscript letter to following sections, however, is generally applicable to all eighteen communities examined as suppliers.

It should also be noted that it has not been possible to go much beyond the short term limits of construction and deal quantitively with impacts on suppliers. Baseline projections are simply not available after 1990 and forecasted impacts are directly related to construction in most every case. Assumptions have had to be made to fill the gaps, but by working within ranges, it is believed gross errors have netted out.

/a/ Land Use

In this impact category, the largest impact can be expected from Alternative No. 3, in which 1,103 acres would be required. However, even in this alternative, the land use changes anticipated are small. Relative to the land resource base of the towns, takings represent about 1% of the total; in Royalston, the largest site, 895 acres compared to a total of 26,880, or 3%, would be affected; in Orange, .16%; in Winchendon, .63%. On the other hand, alternatives No. 1 and 2 would require only about 40 acres of acquisition.

Since existing uses are almost entirely limited to undeveloped open space and since acquisition is likely to mean controlled access, the natural character of the taking area will be preserved. In any event, the service population for any of the alternatives is extremely small and significant principally in the eyes of personally affected individuals.

TABLE 21

IMPACTS ON SUPPLIERS

Impact Category	Measures applied to: Greenfield, Royalston, Athol, Erving, Warwick, Winchendon, Orange	No Project	Alt. #1 Millers	Alt. #2 Tully Millers	Alt. #3 Tully Complex
1. LAND USE /a/ Royalston Winchendon Orange Athol	Net change, % distribution, by use; industrial, commercial, agricultural, residential, recreational; estimated from topo sheets	0	< 1%	< 1%	< 1%
	Net use change, in acres; assuming change for all land taken as an upper limit	0	40	40	1103
	Net change in developable land, percent of land taken	0	.004%	.004%	0.1%
2. POPULATION /b/	Net change in age, race, ethnicity distribution of local populations	0	None	None	None
	Total divergence from baseline trend	0	0	0	0
3. MUNICIPAL FINANCE /c/ Royalston Winchendon Orange Athol	Loss of assessed valuation, % of total, $130,747,427 upper limit	0	< .1 (.014%)	< .1 (.014%)	< 1 (.38%)
	Increased assessed valuation from improved water service	N. A.	N. A.	N. A.	N. A.
	Net change (gain/loss) in tax revenue resulting from improved water service	N. A.	N. A.	N. A.	N. A.
4. COMMERCIAL ACTIVITY /d/	Net change over normal trends in gross wholesale and retail sales of those facilities affected by availability of water resource	0	0	0	0
	Number of businesses displaced by facilities	0	0	0	0
5. HOUSING /e/	Net change in number of housing units. Any relocations (est. 2 - 5 units) expected to be inside supplier area	None	None	None	None

N. A. = not applicable.

TABLE 21 (cont'd)

Impact Category	Measures applied to: Greenfield, Royalston, Athol, Erving, Warwick, Winchendon, Orange	No Project	Alt. #1 Millers	Alt. #2 Tully Millers	Alt. #3 Tully Complex
6. EDUCATION /f/ Greenfield Royalston	Net change in amount of classroom space required for projected change in school-age population resulting from inmigration, upper limit	0	1 primary classroom	1 primary classroom	1 primary classroom
	Net change in cost of teacher and other staff required for projected change in school-age population resulting from in-migration; average salary @ $8,000/annum (1.5 staff per classroom)	0	+$8,400	+$8,400	+$8,400
	Net change in cost of providing school bus services because of changes in housing	0	U	U	U
	Use of facilities for educational programs, upper limit, days/year	0	Not likely	Not likely	Not likely
7. LEISURE /g/ OPPORTUNITIES	Net change in total number of acres of parks and playgrounds	0	0	0	0
	Net change in extent to which planned recreation space meets American Society of Planning Officials planning standards	N. A.	N. A.	N. A.	N. A.
8. CULTURAL OPPORTUNITIES Royalston Winchendon Orange Athol	Total number of churches, historical sites, or other cultural institutions taken	0	0	0	0
	Cost of Relocation	0	0	0	0
	Increase in locational amenities, range	0			0-4
9. TRANSPORTATION /h/	Net change in travel time as a result of facilities construction; minutes/trip times trips/day average 20 minutes delay x 1000 trips/day, during construction	0	0	0	33 + hrs/day

U = data unobtainable at this level of detail.

TABLE 21 (cont'd)

Impact Category	Measures applied to: Greenfield, Royalston, Athol, Erving Warwick, Winchendon, Orange	No Project	Alt. #1 Millers	Alt. #2 Tully Millers	Alt. #3 Tully Complex
10. MUNICIPAL SERVICES	Net change in providing water, sewerage, garbage service and other municipal services	None	None	None	None
Greenfield Winchendon Orange Athol	Net change in residential insurance rates	N. A.	N. A.	N. A.	N. A.
11. SECURITY	Number of positive and negative statements about the opportunity for system failure (new facilities)	N. A.	N. A.	N. A.	N. A.
12. COMMUNITY /i/ IMAGE	Changes in property values adjacent to supply facilities, per holding; totals small in view of limited takings.	0	Average market values around pools: +10% Average market value around structures: -10%		
	Number of positive and negative statements about communities as revealed by content analysis of local news media	0	10-20 aggrieved	10-20 aggrieved	10-20 aggrieved
13. COMMUNITY (See /i/) COHESIVENESS Royalston Winchendon Orange Athol	Total number of community, regional, statewide, and national groups taking a position for or against the project	0	5-10	5-10	5-10
14. CITIZEN- (See /i/) INVOLVEMENT	Total number of community, regional, statewide and national groups involved in planning of the project, times the level of their involvement, according to the following scale: 1. Attendance at hearing. 2. Citizen opportunity to critique plans at public meetings. 3. Periodic workshop planning sessions with community representatives. 4. Community advocate planner participated on equal basis with technical staff. 5. Appointment of arbitrative hearing officer (5 x 8).	0	15-30	15-30	15-30

TABLE 21 (cont'd)

Impact Category	Measures applied to: Greenfield, Royalston, Athol, Erving Warwick, Winchendon, Orange	No Project	Alt. #1 Millers	Alt. #2 Tully Millers	Alt. #3 Tully Complex
15. INSTITUTIONAL INVOLVEMENT	Total number of jurisdictions involved in the totality of the construction process for water supply facilities	0	(1 Town, 1 Municipality State)	(1 Town, 1 Municipality State)	(3 Towns State A. C. E.) 5
	Number of applications submitted to the M. D. C. for water supply service; disposition and frequency of refusal	N. A.	N. A.	N. A.	N. A.
16. ECONOMIC STABILITY (See /d/)	Note change in local economic activity resulting from construction and related activities; 140 x $7,000 x 2 = value added	0	$560,000	$560,000	$560,000
	New increase in private investment	0	0	0	0
17. REAL INCOME	Net change in per capita income; Net change in tax assessments per individual taxpayer Net change in regional income		No significant change anticipated		
18. EMPLOYMENT (See /b/)	Number and type of construction jobs opened; substitution effects not accounted for. P: professional S: skilled U: unskilled	0	30 P 40 S 170 U 240	30 P 40 S 170 U 240	30 P 40 S 170 U 240
	Secondary employment (.2 - .4 times total jobs)		50	50	50
19. INDUSTRIAL ACTIVITY	Change in number of industrial establishments	0	0	0	0
	Change in productivity indices	None	None	None	None
20. AGRICULTURAL ACTIVITY	Change in number of farm (productive) areas, upper limit	0	0	0	50
	Change in production per acre	0	0	0	0

Apart from the recreation issue, in which local residents feel that use and potential use of the land may be curtailed, the development potential of the host towns with any of the alternatives is not thought to be threatened. Given what the towns themselves must recognize as severe geographic disadvantages for industrial growth, it is highly improbable that the sites needed to implement the diversions would ever have appreciable economic value. Their value is chiefly scenic.

/b/ Population

Beyond the labor influx associated with construction of any of the alternative projects, it is highly unlikely that current downward population trends will be reversed. In the decade between 1960 and 1970, no town in the immediate supplier area registered appreciable growth; and Winchendon, Athol and Orange experienced net outmigrations of better than 250 persons each. The principal determinant of any population changes related to the diversions proposed will be the recreation issue. Should the development of recreational facilities take place, it is possible that the supplier area could see a slight increase in residential population, though probably only on a seasonal basis.

Construction-phase labor demands will have at least a temporary effect on suppliers, however. About 170 unskilled construction workers, 40 skilled, and 30 professional people would be employed directly on the various alternative projects.

To determine how the combined incomes of that work force would be distributed, the experience during construction of the Northfield Mountain Hydroelectric facility was utilized. Though the project was much larger -- $90 million, employing a total of some 3,700 persons -- the tasks required (such as tunneling, concreting, carpentry, iron working, pipe fitting, etc.) are of much the same nature as will be required on the diversion works, and project labor is likely to be drawn from the same sources. In a post-audit of the labor force assembled for construction of the pumped storage project,[1] Clark points out that of the 3,368 people employed in the crafts, fully 84% were hired locally, that is, only

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[1] "The Labor Force Associated with the Northfield Pumped-Storage Hydroelectric Project and Its Effects on the Surrounding Communities," Frank Clark, University of Massachusetts, January 1971.

16%, or 477 men moved into the area to obtain project work.[1] The great majority already lived within commuting distance and spent their pay-checks locally. Indeed, aside from those immigrants who established temporary addresses for the term of their employ (principally hard rock miners from North Carolina, New York State and other extraregional areas who were supporting families left behind) salaries were introduced to the economics of Central Massachusetts and southermost New Hampshire and Vermont. Thus, apart from the purchase of meals and incidentals, the salaries of both professionals and the field force were spent within the immediate region but outside the borders of the towns sharing the construction site. As for rents, the largest portion of temporary residents was set up in Greenfield or Montague, Massachusetts rooming houses, housing closer to the construction site being virtually unavailable.

Thus, if the Millers Diversion Project is a "union job" and that is the supposition, the same commutation and spending patterns are likely to apply, though at reduced levels.

/c/ Municipal Finance

One other factor seems especially relevant in the determination of economic impacts caused by any of the alternative projects on supplier areas - the issue of revenues lost to individual towns because of land absorbed into public holdings and thereby removed from the tax roles. In this particular area of the Commonwealth, tax bases in urbanized as well as rural places are not strongly diversified; and thus, even comparatively minor fluctuations can mean local hardship. Efforts made to detect any significant decreases in collectable revenues were largely unsuccessful. In most cases, local officials were unable to identify exact tract ownerships and relate potential takings to assessments.

Once such a computation can be made, an upper limit to such losses can be established by assuming no compensation. Minimum losses, on the other hand, would occur if either or both the government and the Commonwealth were to make payments in lieu of taxes. Although that is the

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[1] The reverse is true for supervisory personnel. Of 355 persons so employed, roughly 60% were immigrants moving to the area for the duration of the project. Most often families were settled in a population center near the project site or in trailer parks in nearby New Hampshire. In terms of spending, however, the same general patterns apply to "wage" staff as to the field force.

intention of the latter authority, it is unclear at present exactly what the terms of such an arrangement might be. The Commonwealth has in the past defrayed such losses to communities affected by flood control project takings, and it is not unlikely that special pleading in the legislature will produce the same result again. However restitution is made finally, the objective is to soften the shock of revenue drops and prevent the deterioration of existing municipal services.

For the purposes of this analysis, it has been assumed that a maximum total decrease of $500,000 (in the case of Alternative No. 3) would result from plan implementation. With respect to the total assessed valuation of the three towns affected, $180,747,427, that amounts to less than a 1% drop. In the case of Alternatives No. 1 and 2 with only a requirement for 40 undeveloped acres of a town total of 20,697 acres, the decrease would be minimal.

/d/ Commercial Activity

With a wide distribution of labor, salary spending should be well diffused, with no one city or town experiencing more than marginal increases in commercial activity. The alternative diversion projects may absorb whatever labor surplus is created by the completion of the Northfield Mountain pumped storage facility and maintain the employment status quo. Of course, since scheduling is uncertain, unemployment conditions at the time of construction are unknowable, and it is possible that the Millers Project will come too late to prevent an employment sag caused by the demobilization at Northfield or offer only substitution effects -- paying salaries obtainable elsewhere in a time of full employment. At present, however, unemployment in Massachusetts is in excess of the national average with a rate of 7.5% compared to the national figure of 5.9%. In the immediate vicinity of the alternative projects in Greenfield, Athol, and Gardner, unemployment is even higher than the State total, with figures of 10.1, 7.7, and 8.5%, respectively. Unless, then, employment opportunities prior to construction alleviate these high unemployment totals, the construction activities of any of the alternatives would provide substantial opportunities for employment. In any event, the diversion construction could well absorb the fifty-odd local hard rock miners trained at the hydroelectric facility.

Beyond the salaries generated, short-term economic impacts also encompass the monies paid to local residents through land acquisition. Neither the magnitude nor the distribution of such payments is readily available.

From the designs prepared to date for the Millers Diversion Alternatives, it is clear that existing public rights of way will be paralleled whenever possible, and that land takings will be held to a minimum. Again, as with salaries, benefits to the regional economy rather than to individuals are to be reckoned not just in terms of dollar totals, but by their fluidity. Clearly, when a land seller receives dollars for his land, it makes a difference to the community whether he saves the money, reinvests it or spends it.

Long-term economic implications for suppliers center largely around the extent to which the volumes of water diverted affect industries now located in the area. As for the first issue, comments made by industry spokesmen at the public meeting held at Athol in late October 1971 indicate a concern for maintaining flows in the Millers River adequate for process purposes. However, it seems safe to conclude that no industrial enterprise will be jeopardized by high flow skimming operations on Millers River and/or its tributaries. In fact, at least in the purely economic sense, the marginal value of the water to be diverted is zero, As such, it must be considered "surplus" and no tangible loss to the local economy.

/e/ Housing

During the construction period of any of the alternative projects, there will be an increased demand for rental housing. Probably, established urban centers at Greenfield, Gardner and Athol or Brattleboro and Keene and Hinsdale (trailers) will absorb whatever non-resident labor force appears and that towns nearer construction sites will not be affected. In no event is the stimulation of new housing construction foreseen. Housing prices and property values may rise for the term of construction but suffer setbacks when the project is completed. Since Greenfield has been identified as an area in which the housing market is sensitive, trends there should be observed as Northfield and Vermont Yankee at Vernon wind down. Adjustments will be required for any data collected to reflect the very much smaller labor force (about 240 as compared with 3,700) anticipated for this construction job.

/f/ Education

From the experience of a dozen different towns surveyed by Northeast Utilities for effects on school populations,[1] only in one, Hinsdale, was overcrowding attributed to worker influxes. It should be kept in mind,

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[1] Bernardston, Deerfield, Erving, Gill, Greenfield, Hinsdale (N. H.), Leyden, Montague, Northfield, Orange, Warwick, Winchester (N. H.).

however, that the nuclear generating station at Vernon, Vermont, and increased business activity in Brattleboro account for much of that effect and obscure the influence of Northfield. Other school systems either had no marked increase in enrollments or cited natural growth rather than project in-migration as the cause of crowding.

As a conservative estimate of impacts felt in the supplier area sample of seven communities, we have used one primary classroom or about twenty youngsters. Noting that Greenfield appears to be a primary response area, we have located the demand there and estimate an average teaching staff expenditure of $8,400.

Busing data were not available. However, because the numbers of new school-age children to be served under the situation caused by construction activities is so small and because their distribution would likely be more general than we have assumed -- that is not just in Greenfield alone -- any change in busing costs would be extremely small. One possible exception is under Alternative No. 3 in the town of Royalston where two road closings and one relocation would be required. Until route lines can be determined for the years in which construction would occur, however, such impacts are strictly speculative.

/g/ Leisure Opportunities

Effects in this category are directly dependent on the extent to which present policies on public access to water supply reservoirs and tributary streams may be modified. If present stringent practices were to apply to the Millers diversion, resident sportsmen and occasional vacationers may be deprived of outdoor recreational opportunities now enjoyed in the upper Millers River watershed. Based on statements made by Massachusetts Department of Public Health spokesmen, it appears that total isolation will not be necessary.

All this notwithstanding, the perception of local residents is that they will be "cheated" of their inalienable rights to free access.[1] The Quabbin experience has rankled in their minds for some thirty years, and references to an MDC "no-man's land" are not uncommon. Their fears are of total exclusion.

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[1] One must, of course, consider non-governmental limitations as well. Privately owned, posted land is as unavailable to the general public as reservations, indeed less so in many cases.

/h/ Transportation

Impacts here which would occur mainly under Alternative No. 3 are certain to be of a temporary nature. The bulk of construction is to take place below the surface with only small dams, pumping stations and occasional access shafts at ground level. Mobility patterns in the resident population may change to some degree, but the dominantly rural nature of the area will make such disruptions infrequent.

The construction contemplated will have almost negligible effects by comparison with the recent highway work on Route 2. Heavy trucking will be required for the removal of spoil to fill areas and the delivery of equipment, but intelligent planning can avoid traffic congestion and hazards to residents. Commutation patterns for the work force will have an appreciable effect on the traffic volumes of major arteries. Locations and magnitudes can be reckoned only after the distribution of labor has been established.

/ i/ Community Image and Cohesiveness

Impacts forecasted for this category for any of the alternatives are very small. No physical separation of populations is involved apart from temporary road closings. No aesthetically undesirable structures are planned, save in the sense that any alteration of the natural scene may be thought of by some as undesirable. Yet, it is in this category that the supply areas themselves feel themselves to be the most injured. Their perceptions of loss are very large, and some commentary seems appropriate.

In terms of standard socio-economic categories like population, density, employment, ethnicity, mobility, etc., and particularly in terms of attitudes, the immediate diversion environs are so homogeneous as to be spoken of as an entity. Indeed, in the sense that they share a common interest in the disposition of Millers River Basin water, they are a single community whose opposition is unanimous.

Because of the nature of the project under consideration, it is revealing to examine the source of the unanimity. Inhabitants feel that the construc tion of Quabbin Reservoir in the late 1930's was a shock to the cultural and economic life of the area from which it has never fully recovered. As the testimony of several local people at the Orange hearing indicated, many of the residents of the towns affected by the proposed Millers Diver· sion Plan consider themselves refugees from the Quabbin site.

Residents of the supplier towns feel themselves to be threatened once again. That is the root of their common cause and the most important cohesive factor in their alliance against the diversion proposed. The social psychology operating here is transference; water for Boston means the bureaucratic machinery of the water supply agency which in turn means wanton despoliation of all that local residents hold dear, and that means a repetition of the upheaval brought by Quabbin in the Millers Basin.

From the impact assessment standpoint, then, even the relatively minor changes brought about by implementation of the diversions will have two principal effects: (1) demonstrate to suppliers that their importance has not changed in thirty-odd years and (2) draw the circle of opposition even more closely together, further alienating it from the political system dominated by Eastern interests. Supplier communities will feel themselves to have been bested yet again and withdraw into a smoldering hostility.

4) The "No Go" Scenario

In the event that one of the Millers River Diversions is not implemented, the single most important impact in the supplier region will be at Quabbin itself. Biological studies have determined that in the event of a near-complete drawdown, the ecologic viability of the reservoir would be endangered. Moreover, as the water area shrinks, the likelihood of odors and exposure of the unsightly bottom area grows. The recreational opportunities at Quabbin are, therefore, considerably diminished, not to mention the consequences for the receivers of Quabbin water which may change perceptibly in color and taste.

Less dramatic are the direct economic and social impacts on suppliers, First, local stimuli caused by construction activity will be zero. Whatever buffer effect the projects might have had on the labor fallout at Vernon and Northfield and on unemployment in the region will be lost. Whatever dollar gains might have been realized by local economies as a result of labor force spending and landtaking costs will be foregone. It should also be pointed out that the difference between tax revenues collected on property not taken and any payments made in lieu of taxes should implementation proceed could be counted as "savings." As noted above, however, revenue data have not been made available, and it can only be assumed that the amounts involved are quite small on the order of several thousands of dollars in the three towns directly affected.

Finally, if none of the alternative projects were implemented, whatever monetary value might accrue to the surplus waters not diverted would be returned locally. This eventuality is highly unlikely, however, because there is no reason to foresee the development of new water-dependent industry in the immediate donor area, at least in the 1975 - 1990 time frame.

5) Impacts on Receiver Area

In the receiver area, which totals sixty-six communities, listed in Table 20, impacts brought about by implementation of one of the alternatives can be expressed in two different ways. First, losses both with and without diversions can be totalled and compared to the costs of providing additional water from the three alternatives. This comparison then provides a basis for assessing the economic efficiency of the alternatives.

Included in the loss totals are industrial, city emergency, city revenue, commerce, sprinkling, business investment and domestic investment losses. However, these loss figures say nothing of the ways in which such losses might be allocated by the various industries and municipalities. An assessment of the potential methods which could be used to allocate these losses (utilizing the socio-economic impact categories given in Table 18) then, is the second method used to express losses in the receiver areas.

To measure the economic losses, a computer simulation model was developed. The model as developed investigated the consequences of a water shortage using as an information base results of a study[1] conducted during the sixties' drought in Massachusetts.

Four major sectors of the communities' economy were differentiated: industrial, commercial, municipal, and domestic. A fifth sector was also used and was comprised of various miscellaneous impacts which could not be conveniently accomodated in any of the above economic sectors. In the analysis, special care was taken to prevent double accounting of losses, that is to make sure losses were counted in only one sector. For example, the MDC and local water departments lose considerable revenue from not being able to sell the water that is unavailable. Since this loss is charged to the MDC and local municipal sectors, the cost of the water not available to the other sectors cannot

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[1] Drought and Water Supply, C. S. Russell, D. G. Arcy, and R. W. Kates, for Resources for the Future.

be charged as a loss to those sectors as well. Their losses should include all the damages in excess of what it would have cost them to purchase the desired amount of water.

To test the impact of water shortages, assumptions regarding the water system facilities to both average runoff and drought conditions similar to those experienced in the sixties were made. Losses associated with both runoff conditions were then calculated. Two major types of losses were distinguished: those experienced annually as a consequence of a shortage and those losses which are experienced once and for all, given a certain shortage level. In the latter category belong all losses connected with investment projects undertaken to either permanently increase the supply of water available to a sector or to permanently decrease the consumption rate of the sector. Once such investment projects are undertaken, the losses that may result may not be experienced again unless the shortage grows more severe. For example, a home owner faced with a water shortage could develop an on-lot supply well to use for his lawn and shrubs. Once this investment is made, he has shielded himself from effects of shortage in future years.

Altogether, seven types of losses were analyzed for their response to water shortage. These are: Annual Losses for the Industrial, Municipal, Revenues Lost to Municipal; Commercial and Domestic Sectors, and Permanent Losses for the Industrial and Domestic Sectors.

The results of the losses which may be expected with the two assumed hydrologic runoff conditions are given in Tables 22 to 24 for the three alternative projects. A full description of the methodology for the evaluation is given in Appendix K.

Utilizing the information contained in Tables 22 to 24, a benefit/cost analysis was made for each of the alternative projects. In developing the benefit/cost ratio shown, a discount rate of 5-7/8 percent and a 50-year project life was used. The losses were estimated on a year by year basis into the future. The capital dollar losses were then brought back to year 0 using present worth single payment factors to get a capital dollar value at year 0. These capital dollar values were then amortized over the life of the project to put them into annual dollar values. The loss figures on an annual basis were then compared with the annual costs[1] of the alternative projects yielding the benefit/cost ratio. These ratios are shown in Table 25. As illustrated, the benefit/cost ratio varies from 1.31 for Alternative No. 1 to 1.0.

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[1] Annual costs shown on Tables 15 - 17.

TABLE 22

LOSSES PREVENTED BY IMPLEMENTATION OF ALTERNATIVE NO. 1 [1]

(1972 Dollars) millions of dollars

Year	Industrial	City Emergency	City - Revenue	Commercial	Sprinkling	Business Investment	Domestic Investment	Total
				Normal (Average) Runoff Conditions				
1982 [2]	.264	.599	1.414	.134	.348	0	1.367	4.125
1990	.502	1.091	2.851	.269	.603	0	.343	5.660
2000	.770	1.547	4.433	.460	.865	0	.311	8.385
2010	.266	.737	3.119	.276	.450	0	.069	4.914
2020	.073	.549	3.012	.261	.379	0	.069	4.343
				Drought Runoff Conditions (sixties drought)				
1978 [2]	.462	1.103	2.286	.230	.648	0	4.910	9.639
1979	1.177	2.746	5.686	.584	1.614	0	24.959	36.766
1980	.449	1.024	2.118	.222	.603	0	-5.551	-1.137
1990	.502	1.091	2.851	.270	.603	0	.083	5.400
2000	.770	1.547	4.433	.460	.865	0	.083	8.157
2010	.266	.737	3.119	.276	.450	0	.029	4.876
2020	.073	.549	3.012	.261	.379	0	.031	4.305

[1] Based on a proportion of yield made available from this Alternative and the Northfield Mountain Project. Tables in Appendix K thus are modified by the ratio 68/140.

[2] Years shown are the dates when restrictions would be necessary based on criteria described in Appendix K.

TABLE 23

CONCRETE LOSSES PREVENTED BY IMPLEMENTATION OF ALTERNATIVE NO. 2 [1]

(1972 Dollars) millions of dollars

Year	Industrial	City Emergency	City Revenue	Commercial	Sprinkling	Business Investment	Domestic Investment	Total
				Normal (Average) Runoff Conditions				
1982 [2]	.279	.633	1.495	.141	.367	0	1.445	4.361
1990	.531	1.153	3.014	.285	.638	0	.363	5.984
2000	.814	1.635	4.687	.486	.914	0	.329	8.865
2010	.621	1.371	5.024	.498	.808	0	.369	8.693
2020	.093	.627	3.478	.296	.430	0	-.182	4.741
				Drought Runoff Conditions (sixties drought)				
1978 [2]	.489	1.166	2.417	.243	.685	0	5.191	10.190
1979	1.244	2.903	6.011	.617	1.707	0	26.387	38.869
1980	.625	1.429	2.958	.309	.842	0	-3.040	3.124
1990	.531	1.153	3.014	.285	.638	0	.088	5.709
2000	.814	1.635	4.687	.486	.914	0	.087	8.623
2010	.247	.781	3.813	.297	.483	0	.022	5.644
2020	.093	.627	3.478	.296	.430	0	-.164	4.760

(1) Based on a proportion of yield made available from this Alternative and the Northfield Mountain Project. Tables in Appendix K thus are modified by the ratio 76/148.

(2) Same footnote as prior table.

TABLE 24

CONCRETE LOSSES PREVENTED BY IMPLEMENTATION OF ALTERNATIVE NO. 3 (1)

(1972 Dollars) millions of dollars

Year	Industrial	City Emergency	City Revenue	Commercial	Sprinkling	Business Investment	Domestic Investment	Total
				Normal (Average) Runoff Conditions				
1982 (2)	.217	.493	1.165	.110	.286	0	1.126	3.397
1990	.414	.898	2.348	.222	.497	0	.282	4.660
2000	.633	1.274	3.650	.379	.712	0	.256	6.903
2010	.157	.482	2.196	.184	.303	0	-.035	3.287
2020	.008	.333	2.039	.163	.239	0	.015	2.797
				Drought Runoff Conditions (sixties drought)				
1978 (2)	.380	.908	1.882	.189	.534	0	4.043	7.937
1979	.969	2.262	4.683	.481	1.329	0	20.555	30.280
1980	.807	1.841	3.810	.399	1.084	0	.124	8.065
1990	.414	.898	2.348	.222	.497	0	.069	4.447
2000	.264	.616	2.294	.188	.354	0	-.066	3.649
2010	.157	.482	2.196	.184	.303	0	-.168	3.154
2020	.008	.333	2.039	.163	.239	0	-.224	2.559

(1) Based on a proportion of yield made available from this Alternative and the Northfield Mountain Project. Tables in Appendix thus are modified by the ratio 48/120.

(2) Same footnote as prior table.

Alternative No. 3 under average rainfall - runoff conditions. With the assumed drought condition superimposed on the water supply system, the benefit/cost ratios vary from 2.04 for Alternative No. 1 to 1.62 for Alternative No. 3.

Based on this analysis, then, all of the alternative projects would provide an economically justified protection for the receiver communities. Alternatives No. 1 and 2 with their higher yield capability and lower costs for water provided offer the better solution with regard to the economic yardstick.

TABLE 25

REGIONAL DEVELOPMENT OBJECTIVE

BENEFIT/COST RATIO

ALTERNATIVE DIVERSION PROJECTS

	Normal Runoff (Average)	Sixties Drought Runoff
Alternative No. 1	1.39	2.04
Alternative No. 2	1.34	2.00
Alternative No. 3	1.16	1.62

As stated earlier, impacts on the receiver areas as the result of water shortages can be expressed two ways. The first, described in the previous sections, counts economic losses which could occur with water use restrictions. The categories included in those totals encompass industrial, city emergency, city revenue, commercial, sprinkling, business investment and domestic investment losses. However, the dollar losses shown do not illustrate how such losses might be allocated. For example, of the more than two million dollars in municipal revenues not collected in 1990 as a result of water shortage, there is no way of knowing whether it would be recreation or education budgets that suffer.

In an attempt to allocate these economic losses, the impact categories described in Table 18 were utilized. Using these categories, Table 26 was constructed. As shown in Table 26, impact category 6 lists loss in classrooms not built as one possible expression of total dollar loss. Similarly, housing units not built are but an alternative manifestation of losses in the private sector. Therefore, to avoid double accounting, the impacts set out in categories 5 and 6 should not be summed with those in other categories.

Still, some quantification of these two important social impacts, as well as those in categories 1 and 7 - 15, was necessary, if only to provide order of magnitude estimates.

To provide the estimates for these categories, an examination was made of the experience of an actual community already beset by the kinds of problems anticipated in the event of prolonged water shortage. Principally, "soft data" related to social impacts were the objective. How does a community respond to the dislocations of water use restrictions? Do citizens get more involved in planning when crisis conditions are sustained over a long period? How quickly does population growth slow in response to water-use and building restrictions? An extended interview with Stoughton's Planning Board Chairman produced both background and impact information.

Stoughton is an industrial - residential community in the Brockton Standard Metropolitan Statistical Area. The town's population of about 25,000 is growing at a rate of more than 40% every decade, and shows no signs of a downward turn. The principal constraint on continuing growth may be an acute shortage of water. Presently, municipal supplies come from five town wells; two recently completed standpipes with capacities of 10 and 2 million gallons, respectively, give Stoughton about 14 million gallons of total storage. The severity of ongoing shortages are indicated by a complete ban on outside watering in effect for several years and a one-year freeze on the issuance of building permits which was lifted last year.

The town has been searching for water since 1955. First, an extensive drilling effort at producing well sites was tried. When the results were negative, consulting engineers were engaged to search for new groundwater sources; results, negative or unacceptable because of high iron content. Last year, a grant of $1.5 million funded a project to clean or replace defective distribution piping. In addition, $150,000 was spent on a connection with Brockton and Canton water supplies. This, however, is seen as only a temporary measure because these two towns can

TABLE 26

IMPACTS ON RECEIVERS

NORMAL RUNOFF CONDITIONS

Impact Category	Measures Applied to Receiver Area (66 elements)	With Alternative Diversion Projects	No Additional Supply
1. LAND USE /a/	Net change, % distribution, by use; industrial, commercial, agricultural, residential, recreational	No change	No differential change general retardation in industrial and residential growth
	Net use change, in acres, for land taken	N. A.	N. A.
	Net change in developable land, as % of land taken	N. A.	N. A.
2. POPULATION /b/	Net divergence from unconstrained baseline trend of: 2,893,100 in 1990;	2,893,100	2,769,600
	4,057,800 in 2020;	3,689,800	3,384,700
	Net change in age race ethnicity, distribution	0	0
3. MUNICIPAL FINANCE /c/	Net change in revenue resulting from water service, 1990	$ 3,108,000[1]	$ 5,870,000
	2020	$15,927,000	$ 18,762,000
	Emergency water expenditures, 1990	$ 1,188,000	$ 2,245,000
	2020	$ 5,043,000	$ 5,542,000
4. COMMERCIAL ACTIVITY /d/	Net change (losses) over normal trends; 1990	$ 294,000	$ 555,000
	2020	$ 2,074,000	$ 2,313,000
	Number of businesses displaced by facilities	N. A.	N. A.
5. HOUSING /e/ Stoughton	Net change in number of new housing units; upper limit (Average decrease 125 units per year)	0	- 3750 units per year

N. A. = Not Applicable U = date unobtainable for calculations at this level of detail

[1] average figures for the three alternatives for all concrete losses shown, all figures in 1972 dollars.

TABLE 26 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	With Alternative Diversion Projects	No Additional Supply
6. EDUCATION /f/	Net change in amount of classroom space required for projected change in school age population; order of magnitude estimate	0	30, twenty-room schools, or 600 rooms not built
	Net change in cost of teaching staff required for projected change in school population (average salary/year = $10,000)	0	900 staff, or $9 million not spent in salaries
	Net change in cost of providing school bus services because of changes in housing	0	U
	Use of facilities for educational programs; upper limit, days/year	20	0
7. LEISURE OPPORTUNITIES	Net change in total number of acres of parks and playgrounds	0	0
	Net change in extent to which planned recreation space meets American Society of Planning Officials standards	N. A.	N. A.
8. CULTURAL OPPORTUNITIES	Total number of churches, historical sites, or other cultural institutions taken	N. A.	N. A.
	Cost of relocation	N. A.	N. A.
	Increase in locational amenities; fountains, pools, etc.	20-30	0
9. TRANSPORTATION	Net change in travel time as a result of facilities construction	N. A.	N. A.
10. MUNICIPAL SERVICES (See /c/)	Net change in providing water, sewerage, garbage service or other municipal services	0	0
	Net change in residential insurance rates	0	0

TABLE 26 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	With Alternative Diversion Projects	No Additional Supply
11. SECURITY /g/	Number of positive and negative statements about the opportunity for system failure	10-20, principally related to radiological hazards of diverting waters downstream of Vernon, Vermont Yankee outfalls	Episodic concern for prolonged and widespread water shortage caused by Quabbin depletion
12. COMMUNITY IMAGE /h/	Changes in property values adjacent to supply facilities	N. A.	N. A.
	Number of positive and negative statements about communities as revealed by content analysis of local media (average 20/year/community); order of magnitude estimate	0	c. 600 Increasing negative comment as watering restrictions put into effect
	Sprinkling losses, 1990 2020	$ 658,000 $2,980,000	$ 1,242,000 $ 3,328,000
13. COMMUNITY COHESIVENESS /h/	Total number of community, regional, statewide and national groups taking a position for or against; average of 4 per community concerned; 3 in favor 1 opposed	90 in favor 30 opposed	100 in favor
14. CITIZEN INVOLVEMENT /h/	Total number of community, regional, statewide and national groups involved in planning of the project X		
	Level of involvement on the following scale: 2 x 60 x 3 1. Attendance at hearing 2. Citizen opportunity to critique plans at public meetings 3. Periodic workshops planning sessions with community representations 4. Community advocate planner participated on equal basis with technical staff 5. Appointment of an arbitrative hearing officer	360	360

TABLE 26 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	With Alternative Diversion Projects	No Additional Supply
15. INSTITUTIONAL INVOLVEMENT	Total number of jurisdictions involved in the totality of the construction process for water supply facilities	No primary sites, connections only; upper limit, 1990 15	N. A.
	Number of applications submitted to M. D. C. for water supply service; disposition and frequency of refusal	30, increasing frequency of admission	30, decreasing frequency of admission
	upper limit, 1990		
	23 "no option" communities 5 actual petitioners (Bedford, Burlington, Reading, North Reading, Wilmington) 2 additional communities		
16. ECONOMIC /i/ STABILITY	Net change in local economic activity; value added derivation from unconstrained supply level of $ 446,000,000 in 1990 $1,398,000,000 in 2020	 $364,800,000 $903,400,000	 $364,800,000 $903,400,000
	Net increase in private investment	0	0
17. REAL INCOME	Net change in per capita income Net change in tax assessments per individual taxpayer Net change in regional income; Total concrete losses, 1990 Total concrete losses, 2020	 $ 6,167,000 $ 30,201,000	 $ 11,650,000 $ 34,149,000
	Total domestic investment losses, 1990 2020	$ 373,000 $ 1,196,000	$ 705,000 $ 1,169,000
18. EMPLOYMENT	Number and type of jobs saved/lost:	0	U Employment falls at about the same % as value added

TABLE 26 (cont'd)

Impact Category	Measures Applied to Receiver Area (66 elements)	With Alternative Diversion Projects	No Additional Supply
19. INDUSTRIAL ACTIVITY	Change in number of industrial establishments	0	U
	Change in productivity		Declines as revealed by declines in value added
	Total industrial investment losses, 1990	$ 547,000	$ 1,034,000
	2020	$ 2,981,000	$ 3,036,000
20. AGRICULTURAL ACTIVITY	Change in number of farm acres, upper limit	N. A.	N. A.
	Change in production per acre	Water used for agricultural purposes is not drawn from public supplies	

terminate the arrangement at will, whenever their capacities are strained. In general, admission to the MDC system is viewed as the only permanent solution. Formal application has been made, but even favorable action means a delay of possibly 8 - 10 years before Quabbin - Wachusett water becomes available.

The consequences of water deprivation have been felt across a wide range of community activities. The following paragraphs, keyed to Table No. 26, discuss the impact of the 1960's drought and the continuing water shortage on the Town of Stoughton, Massachusetts.

/a/ Land Use

Although no shifts in the allocations of land use type have occurred, development in the industrial category has been nearly stopped by water shortage. Interestingly, though a building ban prevented "new starts" on residential housing for a year, the rush to develop after the ban was lifted has more than wiped out any deficit.

/b/ Population

While data projections for longer terms show population deficits for deviations from the "enough supply" situation, it does not appear that population growth is sensitive to short-term controls and constraints. Stoughton's in-migration continued despite the building ban and shows signs of growing even more quickly now that new housing construction has begun again.

/c/ Municipal Finance

Because finding water has been a top town priority, other municipal services have suffered. A sidewalk program has been indefinitely postponed and only minimal roadway maintenance and construction has occurred. Generally, expenditures have been cut as revenues from expected property taxation have dwindled. Estimates range as high as $1,000,000 in tax losses with increases in assessments covering the deficit. The cost of water has doubled in the past two years and the municipal debt as of January 1, 1970 stood at $7,516,000 or $320 per capita. Until a mutual help agreement was reached with Easton and Sharon, adequate fire protection was a critical concern.

/d/ Commercial Activity

In the time observed by the interviewee, there have been no perceptible consequences for either retail or wholesale trade.

/e/ Housing

Since the lifting of the building ban, over 500 rental units have been built and occupied. The demand for housing has lowered the vacancy rates significantly and stimulated the construction of 3,000 apartment units and the planned development of 3,000 more. Before the ban went into effect, issuances of building permits had declined an average of about 130 units per year for two successive years.

/f/ Education

Two primary schools of twenty-six classrooms each have been completed in the past two years (September 1970 and 1971) to accomodate a swelling elementary-age school population. A much-needed junior high has been put off -- an effect attributed to the "extraordinarily high expenditures of finding water." As a result, the present junior high is expected to go into double sessions this coming fall.

/g/ Security

As the search for water has become "business as usual," citizens appear to have developed some tolerances for the inconvenience of watering bans. However, their latent insecurity about adequate supplies for fire protection and general domestic consumption have made water shortage a perennial political issue on which concern can focus. As noted above, the prevailing attitude is that "everything will be all right" once MDC admission is secured and the burden of water planning can be shifted to the Commission.

/h/ Community Image

Despite the general slowdown in industrial development and its second order consequences on town revenues, the average citizen perceives the water supply problem in terms of his own inability to water outdoors. Lawns and shrubbery are a waste of money, says the homeowner, and the town looks poorer for it. A general feeling of discouragement and frustration has set in and the desireability of Stoughton as a residential community has been adversely affected. So far no monetary reflections of this malaise have developed and property values are as yet unchanged by water shortage.

/i/ Economic Stability

Economic development has been hurt because water using industries have been turned away. This has "slightly decreased" the stability of the town because the tax base has not expanded quickly enough to keep up with demands on local revenues. Wages and prices have remained in phase with the rest of the state, but taxes have increased.

/j/ Industrial Activity

No Stoughton industries have left because of water shortage, but new industries (chemical plant, refinery) have gone elsewhere. Presently, only non-manufacturing, non-processing firms are permitted to locate in town, and a $40 million industrial park is now two years behind in its development schedule.

Using data collected in the Stoughton case study, adjustments were made to reflect forecasts of impacts on the receiver area. In every case, values were multiplied by a factor of thirty: twenty-four "no option" communities for whom prolonged water shortages could be especially severe and six others, roughly one out of every three now "partially served" or served non-members. Since the impact estimates produced in this manner are undoubtedly high, no separate account was taken of communities already fully served. That is, for example, the thirty, twenty-room schools not built because of slowed population growth in the "no go" situation represent a system maximum whether or not it is precisely the "no option" or "partially served" communities which fail to erect them.

One further note should be made regarding Table 26. The data shown with the exception of the values presented for the seven loss categories described earlier were not adjusted for the varying yield of the three alternative projects. Since the other data is qualitative, it was felt adjustments to further refine the information was not warranted. In addition, the With Alternative Diversion Projects column reflects a satisfied condition, that is, water demands are met. To meet water demands, however, another supply project would be needed. That other project, the Northfield Mountain development, is the subject of a separate, but companion report.

Social impacts, then, in the receiver area are principally "shadow costs" of concrete losses generated by water shortage. As municipal efforts turn to finding new sources, building bans to hold the line on new demand are a likely eventuality. Second-order effects of expenditures on water searching manifest themselves as slowed school building programs, poorer municipal services (especially fire protection) and a general malaise in the development plans of the subject towns. Moreover, it appears that citizens are likely to become discouraged and frustrated as they see their lawns dry up during watering bans. In many ways, these feelings are reflected in attitudes about the desirability of their town as a place to live and work.

Short-term, project-specific impacts on receiver areas are seen as virtually non-existent. Remembering that no actual water deliveries from the Connecticut Basin would be made short of five years from the start of construction, economic impacts perceived in the MDC service area would not be water-related. For example, it might be that certain portions of the supervisory and office labor force required for construction might come from cities and towns incidentially served by the MDC. Or, it is possible that equipment required for construction or permanent installation may bring revenues to a jurisdiction classified as a receiver. However, such stimuli are likely to be very small indeed because the dichotomy between supplier and receiver areas is nearly perfect.

Long-term impacts -- those generated by the availability of that yield increment provided by the diversions -- are more tangible. In a general sense, receiver areas will continue to develop along the optimistic lines suggested by their respective Master Plans.[1] Therefore, interruption of service is not expected to occur and industry, especially, can be free of nagging doubts about the risks of water use restrictions. Developers of residential housing slated for existing MDC service communities and those expected to join before 1990 are not likely to take their investments elsewhere as a result of threatened water shortages.

With respect to the water supplied itself, receiver communities benefit from implementation of the diversions in two specific ways. First, exceptionally high water quality will not change. Households and industrial establishments accustomed to minimally treated upland water supplies will not be required to tolerate or compensate for waters of lower quality until such time as even the Connecticut diversions become inadequate to meet demand. This will be particularly important to manufacturers using large amounts of water for purposes other than cooling and those to whom deferred investments in treatment and recycling are desirable. Likewise, homeowners will not have to search for other sources of supply and sustain the cost of sprinkling losses. Moreover, it is unlikely that MDC members will be subjected to the large price hikes that may be associated with the restrictions imposed earlier under a no-go condition.

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[1] These documents uniformly assume unconstrained water supplies in their development of growth expectations.

B. National Economic Development Account

The National Economic Development (NED) objective is enhanced by increasing the value of the nation's output of goods and services and improving national economic efficiency. Components of the NED objective include:

1) The value to users of increased outputs of goods and services resulting from a plan. For example, the projects reported upon in this study would reduce descriptions of economic activity due to water supply shortages, thus leading to direct increases in productivity from water and land development that contribute to national output.

2) The value of output resulting from external economics. In addition to the value of goods and services derived by users of outputs of a plan, there may be external gains to other individuals or groups. For example, the projects included in this study would maintain a viable economy in receiver communities. Such maintenance of a strong economy in the northeast would then benefit the nation as a whole.

In the assessment of the alternative projects' impact on the NED account, much reliance was placed on the economic loss categories described earlier. For purposes of this study, such social impacts were only carried in the Regional Development account. The reader should be cautioned, however, that the economic losses described in the following paragraphs are not all inclusive of losses which may be sustained without the availability of additional supply.

In evaluating the economic losses prevented by implementation of any of the alternative projects, seven loss categories were examined. These are: Annual Losses to the: industrial, municipal - emergency, municipal - lost revenue, commercial and domestic sectors; Permanent losses to industrial and domestic sectors.

Upon examining the losses in each category, it was decided that losses in four of the categories, municipal - emergency, municipal - lost revenue, domestic annual losses and investment, represented losses to the nation as a whole. These four categories, therefore, were carried fully from the Regional Development account into this account.

The remaining three loss categories investigated, industrial business losses, commercial losses and industrial investment losses, were felt to more represent regional rather than national losses. That is, elements in these three categories which suffered losses in the region could be replaced by increased business activity in other parts of the nation.

Based on the four loss categories considered affecting the NED objective, a benefit/cost ratio for each of the three alternatives was constructed and is presented in Table 27.

As illustrated, the benefit/cost ratio for the three alternatives varies under normal (or average) hydrologic runoff conditions from 0.9 for Alternative No. 3 to 1.1 for Alternative No. 1&2. Under sixties' drought conditions, the benefit/cost ration varies from 1.4 for Alternative No. 3 to 1.8 for Alternative No. 1.

Based solely on economic losses, then, two of the alternatives would prevent more losses to the national economic development objective than the costs of implementing one of the alternatives. In addition, as stated earlier, these economic benefit/cost ratios do not reflect the social impacts to the nation which might be occasioned by water shortages. If these social impacts, described under the Regional Development account, are also considered as affecting the nation as a whole, then the effects of water shortage on the National Economic Development account are multiplied.

TABLE 27

NATIONAL ECONOMIC DEVELOPMENT OBJECTIVE
BENEFIT/COST RATIO
ALTERNATIVE DIVERSION PROJECTS

	Normal Runoff (Average)	Sixties Drought Runoff
Alternative No. 1	1.1	1.8
Alternative No. 2	1.1	1.6
Alternative No. 3	0.9	1.4

C. Environmental Quality Account

1) General

From the outset of this report, efforts have been made to determine the impact of the Millers River Basin water supply diversion elements on the environment. An evaluation was made of the project's impact on the Connecticut River estuary, on the Connecticut and Millers Rivers downstream from the point of diversion and on the environment of the receiving water storage reservoir, i. e., Quabbin.

To conduct these investigations, both in-house capability of the New England Division's Environmental Resources Section, as well as contractor personnel, were utilized. The following sections describe the efforts of this integrated multi-discipline team of both Corps of Engineer personnel and services from two environmental consulting firms.

2) Possible Environmental Impacts of Diversion on the Connecticut River Estuary

In evaluating the possible environmental impacts which might occur within the Connecticut River estuary, contractor services were utilized extensively. Recognizing that this report's alternative project's diversion rates are small in comparison to the total Connecticut River flow and that other proposals for diversion were also being considered in the Connecticut River[1] Basin, it was decided to test effects[2] which might occur with a large range of postulated diversion rates.

The range of postulated diversion rates tested varied from 600 cfs to 4000 cfs with adherence to a minimum control flow at Montague City of 17,000 cfs and 12,000 cfs, as measured at the U. S. Geological Survey gaging station. Only the 17,000 cfs control flow rate has been approved by the Massachusetts Legislature.

The use of the large range of postulated diversion rates, i. e., 600 to 4000 cfs, with corresponding control flow rates of 17,000 and 12,000 cfs, thus were adopted to allow a full investigation of any potential impacts on the estuary. For example, if the larger postulated diversion

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[1] Subject of a Companion Report: The Northfield Mountain Water Supply Project.

[2] Possible Effects of Various Diversions from the Connecticut River Estuary, Essex Marine Laboratory, Inc., May 1972, Prepared for the New England Division, Corps of Engineers.

rates were tested and limited impact predicted, then the lower diversion rates actually proposed could be expected to exhibit even less of an impact. This, in fact, is what the results of the study concluded as summarized in the following paragraphs. A complete description of the study is given in Appendix J.

a) Changes in river temperature due to diversion should not exceed 0.61° F under the worst case postulated (i.e. 12,000 cfs at Montague City and 4,000 cfs diversion). Although many biological effects of temperature elevations are well known, in most cases the effects resulting from such a small temperature increment are too small to quantify.

Biological evaluations were made using a 2° F temperature rise in the estuary. The rationale for choosing this temperature rise is twofold. First, biological changes could not be predicted on much less than a 2° F increment of change; and secondly, it would be only an academic exercise to try to refine predictions at a smaller increment of change if, in fact, no significant changes would occur at the 2° F increment. As it turns out, even a 2° F temperature rise would not cause a serious impediment to diversion plans as far as the ecological balance of the estuary is concerned. Keeping in mind that the calculated temperature rise is less than 1/3 the value used in biological evaluation (.61° F vs. 2° F), the reader is advised of the apparent conservative nature of the biological evaluation that is summarized in the following paragraphs.

Among the known biological effects of increased temperature, the following may be expected, but it should be kept in mind that even if deleterious, the small change in temperature will result in too small a magnitude of change to be cause for alarm.

All of the conclusions regarding temperature and biological change are based on the worst condition tested, i.e., 4000 cfs diversion with 12,000 cfs at Montague City.

(1) <u>Change in the Time and Location of Shad Spawning</u> - Calculations indicate that a 2° F temperature rise in the river water would have caused spawning to occur 3.4 days earlier in 1967 and 3.6 days earlier in 1968. It is postulated that the most severe postulated diversion conditions would have an insignificant effect on shad spawning.

(2) <u>Shad Egg Size, Abundance, Development Time, and Mortality</u> - Shad spawning success in general will not be greatly influenced by any of the postulated diversion. After diversion, temperatures would still remain well within normally occurring variations;

and since spawning occurs well above salinity intrusion, any changes in salinity patterns will not affect spawning.

(3) Effects of Survival of Larvae of Shad and Resident Fish Species - Temperature rise and salinity changes that would be brought about by postulated diversion are not expected to affect the egg or larval survival development or growth of any of the fish species tested.

(4) Adult Fish Populations - Some adult fish could feel an effect of the diversion as a result of shifting (in time) of the availability of a food supply. Food generally becomes available as temperatures exceed 40° F. A 2° F temperature rise would have caused this 40°F temperature to be reached 4.3 and 6.8 days earlier in 1969 and 1970, respectively. Since some adult fish winter in coves and do not move out into the river until temperatures reach 40° F in the coves, they may arrive in the river up to a week after the food supply begins to develop. This assumes that water temperature in the coves would not be influenced by the 2° F temperature rise in the river. More information is needed in this area to draw any definite conclusions, but no problem of significant proportions is anticipated.

(5) *Homing Ability and Timing of Arrival of Adult Shad* - Adult shad appear to have no homing problems even during extreme low flow springs. Diversion will not reduce flows during these extreme low flow conditions so that it is logical to assume that the shad's homing will not be impaired by diversion. Historically, it has been found that shad tend to enter the estuary when temperatures reach 40° to 43° F. Diversion would cause these temperatures to be reached somewhat earlier, but no problem is anticipated.

(6) Microbiological Population - Because of the paucity of data in some critical areas of basic biology, deemed pertinent considering the postulated diversion, no absolute predictions can be made regarding the ultimate fate of microorganisms in the estuary. Since temperature and salinity rise are so small (2° F and a few mg/l) at any given point and since these changes develop over a period of time, no significant qualitative or quantitative alterations of bacterial populations are to be expected in the short run (a few years). Beyond this span, any prediction would be speculative.

(7) Invertebrates - 48 recurring species of invertebrates have been identified in 60 months of sampling. Of these, four species are dominant. A 2° F temperature increase can be expected to increase the metabolic activity and probably advance sexual maturity

slightly in each of the above species. However, since considered diversions will not be made during summer low flow, high temperature situations, these species are not put under any undue stress. Temperatures after diversion will still be well within the limits of naturally occurring variation, and only minimal adverse effects are to be expected.

b) Freshet conditions should continue throughout the estuary if no diversion takes place when flows are less than 17,000 cfs at Montague City. The duration of freshet will be shortened by 2 to 4 days at both the onset and cessation of freshet in a normal year with diversion. If 12,000 cfs were considered as a control flow, then freshet conditions would be shortened by 3 to 9 days at both the onset and cessation of freshet in a normal year.

c) At a 12,000 cfs controlling flow at Montague City, minor reversals of current may occur in the lower estuary. These should not be sufficient to cause a biologically significant intrusion of salt water from Long Island Sound.

d) Under either controlling flow regime, changes in salinity distribution would be too small to have measurable biological effects.

3) Possible Environmental Impacts of Diversion on the Connecticut River

a) General

The Connecticut River itself is the largest river basin within New England. The river drains an area of 11,265 square miles of which about 7,200 square miles are located upstream of the proposed diversion intake.

Downstream from the Millers River confluence, the river flows south for about 63 miles prior to the tidal portion of the basin. In this downstream reach, the river flows through rural as well as highly populated centers such as Springfield, Chicopee, and Holyoke, Massachusetts, and Hartford, Connecticut.

Historically, the Connecticut River has supported major runs of anadromous fishes, including American shad, alewives, blueback herring, rainbow smelt, sturgeon, and Atlantic salmon. Though the first four of these species still complete their annual migrations for spawning within the lower reach, all were eliminated from the upper portion subsequent to dam construction. The Atlantic salmon has been entirely eliminated. A sport fishery does exist throughout the river's length; however, it reaches peak importance along the tributaries, which receive annual stockings of trout to maintain a "put-and-take" sport fishery. Present efforts are being expended to restore anadromous fish to the entire watershed through construction of fish passage facilities at obstructions not having these structures and through re-introduction of salmon. Pollution abatement within the entire watershed is expected to lead to restoration of high quality aquatic resources and their utilization.

As described earlier, the alternative diversions for water supply purposes would withdraw a maximum daily flow of 730 cfs from the river, and this flow would then be conveyed to Quabbin Reservoir. Diversions would only be made contingent on a minimum control flow of 17,000 cfs as measured at the U. S. Geological Survey gaging station at Montague City, and upon control flows at the various diversion intakes themselves.

Based on long-term stream flow records maintained at the Turners Falls Dam, the amount of water to be withdrawn would be about 1% of the average annual run-off from the river. In addition, the maximum decrease in river stage caused by the diversion would be about .27 feet at Montague City or about .09 feet at the Thompsonville, Connecticut gage. Since, for example, the average depth at Montague City at 17,000 cfs is 12.75 feet, the decrease caused by the diversion is minimal.

b) Change in Concentrations of Nutrients

Based on data developed by the University of Massachusetts as part of a research grant, ammonia - nitrogen loads in the Connecticut River at Northfield for 1963 - 1965 were 3,800 pounds per day. Downstream at Thompsonville, Connecticut, loads for the same period were recorded as 35,900 pounds per day. Phosphate - phosphorous at Northfield for 1963 - 1965 was estimated to be 6,700 pounds per day, while at Thompsonville, about 33,000 pounds per day were recorded.

The diversion from the alternative projects would little affect nutrient levels downstream from the diversion. Maximum differences in concentrations at Thompsonville for ammonia - nitrogen and phosphate - phosphorous would be about .01 ppm.

Since pollution abatement schedules call for installation of waste treatment facilities by 1976, the actual effect of diversion would be even less.

c) Change in Coliform Levels

Work conducted at the University of Massachusetts on this subject regarding the proposed Northfield Mountain Project had among its conclusions, "A diversion of Connecticut River water at Northfield would reduce the flow and increase the coliform concentration. This seems reasonable since relatively coliform-free dilution water would be diverted. However, a reduction in flow at Northfield caused by the proposed rate of diversion would probably have no significant effect on coliform concentration at Enfield." This report feels a similar conclusion could be made on the impact of Millers River regarding diversions.

d) Effect on Downstream Wetlands

As stated earlier, the diversion at Northfield would lower river stages at Montague City 0.27 feet at a maximum. Downstream at Thompsonville, the stage reduction would be .09 feet. Minimal impacts to downstream wetlands are foreseen for these limited river stage reductions.

e) Effect on Planned Water Quality Improvements

Implementation schedules for waste treatment facilities on point sources of pollution have been established by the Environmental Protection Agency and the basin states. All plans for pollution abatement are based on meeting adopted water quality standards during low flow conditions. Since diversions considered in this project would only occur during high flow periods when flow is 17,000 cfs or greater at Montague City, no impact would occur to impair planned water quality goals.

f) Effect on Water Temperature

Studies conducted within the estuarine portion of the basin indicated a maximum of 0.12°F rise could be expected in the estuary following diversion of 730 cfs. Upstream in the mainstem of the Connecticut River, the maximum change in temperature which would be caused by the diversion and subsequent loss of dilution flow would be about 4.3%. No significant effect on water temperature is anticipated, therefore, from the diversion.

g) Change in Level of Groundwater Level

A meeting was held with the U. S. Geological Survey to determine the impact which the diversion may have on groundwater levels. In the opinion of the Geological Survey, no significant impact to groundwater levels is anticipated as a result of the diversion.

h) Effect of Diversion in Flood Flow Bottom Deposit Scouring

Based on studies by the University of Massachusetts, it was estimated that sediment load transport efficiency of the Connecticut River just downstream of the confluence of the Millers and Connecticut Rivers would be reduced approximately 3 percent. Downstream from the intake, flow from intervening drainage area would cause the reduction in efficiency to be even less.

i) Effect on Downstream Navigation

Below Hartford, Connecticut, the river is used for both commercial shipping and recreational boating. Upstream from Hartford to Holyoke, the river is used for recreational boating, but sand bars and shallow water during low flow greatly impede navigational use.

Normal navigation season flow at Hartford is considered to be 3,750 cfs, while the upper limit is considered to be 66,000 cfs.

The diversion would not affect low flow navigation conditions. High flow conditions would be affected, but not in a negative manner. Instead, the reduction in flow from the diversion would be a minor benefit due to slightly lower velocities.

4) Possible Environmental Impacts of Diversion on the Millers River Basin

a) General

The Millers River rises in Ashburnham, Massachusetts, and flows in a westerly direction for about 45 miles through Winchendon, Athol and Orange to its confluence[1] with the Connecticut River at Montague and Erving, Massachusetts. It has a total drainage area of 392 square miles.

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[1] near Northfield, Massachusetts, referred to in the prior paragraphs.

Principal tributaries of the Millers River are the Otter and Tully Rivers. The Millers Basin is characterized by 78% forest cover, 11% open land, 8% wetland, and 3% urban area.

The mainstem of the Millers River at present contains both treated and untreated domestic sewerage and substantial amounts of industrial wastes from several communities. The Otter River, one of the main tributaries to the Millers, is also heavily polluted with municipal and industrial waste. The tributaries of the Millers River, however, are relatively free of pollution and are of good quality.

Two distinct stream-type zones are apparent on the river between Athol and its confluence with the Connecticut River. From Athol, extending downstream to the Orange dam, the setting is a wide level valley with the river meandering through an agricultural setting of pastures, meadows, and settled land. The stream bottom is mud and silt with extensive emergent vegetation as is the outlet of Lake Rohunta which joins the Millers River below Athol. The river is backed up by the Orange Dam about a mile upstream. The zone between Orange and the Connecticut River is typified by steep banks, a sharp river gradient, long rapids followed by short pools, a complete absence of wetlands, and a boulder strewn, rock rubble bottom.

Within the basin, good trout habitat exists upstream of the Millers River confluence with the Otter River. In these upstream reaches, the streams are stocked annually with rainbow trout by the Massachusetts Division of Fish and Game on a "put-and-take" basis. In the Otter River and downstream reaches of the Millers River itself, however, existing pollution has made a sport fishery non-existent. Fish species in these reaches consist primarily of suckers and bullhead.

Water based and associated land based recreation within the basin is severely curtailed by the existing pollution problems. However, white water canoeing is a popular recreational activity during the high spring runoff periods.

b) Possible Impacts on the Millers River Downstream from the Confluence of the Tully River

Possible impacts caused by implementation of any of the alternative projects on the Millers River downstream from the confluence of the Tully River would be similar. This general similarity is occassioned by the fact that all of the alternatives would withdraw water upstream from the Millers - Tully River confluence.

The effect of diversion on river flow will be most pronounced at the confluence of the Tully and Millers Rivers in Athol, Massachusetts. Up to 31% of the monthly flow may be diverted during an average year. However, in no case would the flow in the river be reduced below the established rate necessary to protect the river environment.

The possible impact of the diversions on ground water recharge was assessed. To aid in this evaluation, the U. S. Geological Survey (USGS) were asked for their expert opinion. With regard to the possible impacts below the Millers - Tully confluence, the USGS stated "Since operation of Birch Hill and Tully Reservoirs prevent overbank flooding, the proposed diversions will have no effect on ground water recharge from flood plains below the reservoirs."

If the diversions were in operation with existing water quality conditions in the Millers River, some degradation of water quality could occur. However, plans for the implementation of secondary waste treatment facilities call for construction of the treatment plants by 1974. Earliest implementation of any of the alternative water supply projects would be in 1981 - 1983. Thus, these facilities would follow construction of the planned secondary treatment plants. The design criteria for these sewage treatment plants is based on receiving water flow during low flow conditions. In all alternatives, diversions would take place during high flow periods; thus, the diversions would not affect the ability of the river to meet adopted water quality standards.

In Alternatives No. 1 and 2, the provision of advanced waste treatment facilities to insure water quality suitable for water supply purposes is included. Therefore, the implementation of either of these alternatives would improve Millers River quality over that presently planned. Impact of these alternatives would be an enhancement of the basin's environment.

Because of the total volume of water which would be diverted with any of the alternatives, a lessening of the sediment transport and "flushing" action normally experienced in the Millers River could be expected. During the 1971 and 1972 spring runoff period, paper pulp in suspension was noted within the Millers River. Apparently, the turbulence associated with high flow can scour some deposits of pulp and carry them downstream, thereby partially cleansing the bottom habitats. Reduction in peak flows from any of the diversion alternatives, if they were operational, now would tend to reduce the effectiveness of this cleansing action. However, the existing uncontrolled flows are not adequate to clean the river. It is necessary to stop the input of pulp before this suspended load can be reduced. After the planned waste treatment described in the previous paragraph is in operation, the pulp load released to the river will be substantially reduced. Since any diversion considered would occur after the waste treatment plants are in operation, any impact of diversion on "flushing" action should be minimal.

Flow diverted by any of the alternatives may cause a slight temperature difference in the Millers River. Temperature records in the tributaries and the mainstem Millers River during proposed diversion periods do not indicate any major differences during the proposed diversion period. Since flow rates in the tributaries and mainstem differ significantly while temperatures are generally similar, there is no indication that lowering flow rates would cause a major temperature rise or decrease in the Millers.

The maximum calculated decrease in river stage at the Main Street Bridge in Athol, Massachusetts, which would be caused by the diversions, is about 1.5 feet. If the basin had a shallow gradient, which it doesn't, such as many of the coastal streams in eastern Massachusetts, such a decrease might have many environmental considerations. A careful examination, however, of the downstream flood plains which would not be inundated due to this decrease revealed limited areas. Therefore, impacts due to decreased river stages which could be expected on any downstream areas which receive water infrequently are expected to be minimal.

Several cold water species such as trout are now found only in the upstream tributaries while limited species are found in the Millers River itself. Following completion of planned secondary waste treatment and treatment facilities included in Alternatives No. 1 and 2, fishing opportunities should increase. Diversions would only take place during periods of high flow so that fish passage would not be obstructed by any of the projects during the remainder of the year. In any event, the existing species and any new species would be locked in segments of the river by the existing major dams at Athol, Orange and Millers Falls.

At present, portions of the Millers River mainstem are attractive to the canoe enthusiast.[1] The three reaches of river that would be affected by reduced flows are: 1) South Royalston to Athol, 18 miles described as mostly rapid, very attractive and passable at high water only;

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[1] A.M.C. New England Canoeing Guide, Published by the Appalachian Mountain Club, 1968 - Vermont Printing Company.

2) Athol to Erving, 11 miles not recommended, mostly smooth and only fair attractiveness; 3) Erving to Millers Falls, 6 miles, mostly rapid and very attractive.

Impacts on canoeing in the mainstem Millers River caused by Alternative Nos. 1 and 2 on the three river reaches described above are as follows:

(1) For Reach 1 - South Royalston to Athol, no impacts would occur upstream from the Millers River intake (approximately 16.5 miles). Downstream from the intake, decreased flow may be beneficial during periods of extreme high water; however, diversion may shorten the season on this 1.5 mile reach during lower flow periods in late spring.

(2) For Reach 2 - Athol to Erving, there may be a possible lessening of the available canoeing season. However, this reach is characterized as only "fair attractiveness," thus impacts should be limited.

(3) For Reach 3 - Erving to Millers Falls, decreased flow may be beneficial during periods of extreme high water, but diversion may also shorten the season during lower flow periods in late spring. The impact of diversions would be decreased, however, by the contribution of intervening drainage area to river flow.

5) Possible Impacts of the Alternative Projects on Their Immediate Environment

a) Alternative No. 1 - Millers River Diversion

(1) Environmental Setting

For this alternative, water would be diverted from a 15 acre, 1/2 mile long pool on the mainstem of the Millers River, about 1-1/2 miles above Athol, Massachusetts. Facilities required would include an inlet structure on the Millers River, a 10-foot diameter tunnel to Quabbin Reservoir and an outlet structure within the reservoir itself. Investigations conducted to date indicate proposed pollution abatement plans by Massachusetts State Agencies, include secondary treatment on all point sources of pollution. Additional treatment would be necessary to insure a good water supply source. Advanced waste treatment facilities, therefore, have been included as an element in this alternative.

(2) Inundation of Land at Millers River Intake

Alternative No. 1 would seasonally inundate 15 acres and 1/2 mile of the Millers River mainstem. The small pool created by the diversion weir would only exist seasonally; so during other than diversion periods, no pool would exist. Diversion will take place only during periods of high flow so that fish passage would not be obstructed by the project during the remainder of the year (they are presently locked in sediments of the river by major dams at Athol, Orange, and Millers Falls).

b) Alternative No. 2 - Millers-Tully Diversion

(1) Environmental Setting

In this plan, diversion from the Millers River Basin would be accompanied via withdrawals from the East Branch Tully River and the mainstem of the Millers River above Athol, Massachusetts. Facilities necessary for development would include a morning glory type inlet structure just downstream from the existing Tully flood control reservoir and an 8-foot diameter tunnel to the Millers River above Athol. At the Millers River, a second tunnel inlet would be constructed and connected to the aqueduct from Tully; and from this location, a 10-foot tunnel would be driven to Quabbin Reservoir where water would be discharged through an outlet structure. As in Alternative No. 1, advanced waste treatment plants would be required on seven point sources of pollution. The plan would seasonally inundate 15 acres and 1/2 mile of the Millers mainstem.

This alternative essentially results from the combining of Alternative No. 1 with the addition of a supplementary diversion from the East Branch Tully River to the diversion point on the Millers River, discussed under Alternative No. 1.

The environmental setting of the Tully sub-basin will be discussed under Alternative No. 3 which follows. However, unlike Alternative No. 3, Alternative No. 2 requires no storage at the existing Tully Lake.

(2) Inundation of the Millers River Mainstem

The same structure is envisioned on the Millers River Mainstem for both Alternative No. 2 and Alternative No. 1. Impacts discussed under Alternative No. 1 also apply to Alternative No. 2.

(3) Reduction in Flow

(a) In the Tully River - the reduction of flow of the Tully River between Tully Dam and the confluence of the Millers River would be approximately 23% of the monthly average for March, April, and May. It is expected that the environmental impact of flow reduction on the Tully River and the East Branch Tully River below Tully Dam will be similar to that discussed under Alternative No. 3. This is due to the fact that comparable percentages of water will be diverted.

(b) In the Millers River - Since this alternative essentially results from the combining of Alternative No. 1 with the addition of a supplementary diversion from the East Branch of the Tully River to the diversion point on the Millers River, there would be no additional impact on the Millers River below the diversion point beyond that previously described in Possible Impacts on the Millers River downstream from the confluence of the Tully River.

c) Alternative No. 3 - Tully Complex Diversion

(1) Environmental Setting

The Alternative No. 3 plan for making diversions from the Millers River Basin involves the construction of an 8-foot diameter tunnel from Tully Lake to Quabbin Reservoir, a dam on Priest Brook, and diversion structures on Tarbell Brook and West Branch Tully River. Water would be diverted in a pressure conduit from Tarbell Brook to the proposed Priest Brook ponding area. Pumping facilities at the Priest Brook Dam would convey this water together with Priest Brook water to Tully Lake. A gravity feed tunnel would then divert the two brooks' water plus the East Branch Tully water out of the basin to Quabbin Reservoir. Water from the West Branch Tully could then be pumped into the tunnel near the confluence of the East and West Branches of the Tully River. Recreation and wildlife management programs are also included at these diversion sites.

(a) Tarbell Brook Diversion

Tarbell Brook is a small, low gradient stream approximately 7-1/2 miles long from its headwaters to its confluence with the Millers River. Open water areas (which include lakes and ponds) along the stream cover 1-1/2 miles. The total drainage area is approximately 27 square miles of which about 5 are wetland, less than 2 are open water, and the remaining area representing upland habitat.

Flow is moderately rapid through forested areas and slow in open wetland areas. Stream width varies up to 30 feet. Depth is variable and measures several feet in some places. Water quality is good (Class B). The adjacent habitat is primarily coniferous forest combined with mixed stands of hardwoods.

The stream is stocked annually with trout by the Massachusetts Division of Fisheries and Game which provides a "put-and-take" sport fishery. Several species of game such as woodcock, grouse, black duck, rabbit, squirrel, and deer inhabit the area.

The proposed diversion site would be located on Tarbell about 1/2 mile above its confluence with the Millers River and approximately 2-1/2 miles northwest of Winchendon, Massachusetts.

If implemented, the project will seasonally inundate 40 acres of wetland habitat to a depth of 5 feet, including 1/2 mile of free flowing stream.

(b) Priest Brook Diversion

Priest Brook, including Scott Brook, (its main northern tributary) extends approximately 14 miles from its headwaters in southern New Hampshire to its confluence with the Millers River. Open water areas cover one mile along the stream which is of moderate to low gradient and flows through forested and wetland areas. Width varies up to 40 feet and depth is variable, generally three feet but as much as six in some areas.

The total drainage area is approximately 23 square miles of which about three are wetland, less than one is open water, and the remaining area is upland habitat. Water quality is good (Class B) but below average for trout during summer months due to high temperature and low flow conditions. Adjacent habitat consists of coniferous forest with mixed stands of hardwoods.

This stream is stocked annually with trout by the Massachusetts Division of Fisheries and Game which provides a "put-and-take" sport fishery. Waterfowl and other game species are essentially similar in type and number to that found in the Tarbell Brook watershed.

The proposed diversion site would be located approximately four miles due east of the town of Royalston in an unpopulated area, three miles above the confluence with the Millers River. The project area will encompass about 400 acres, including approximately 330 acres of wetland and 70 acres of upland habitat.

The following private developments are located within the project area: an extensive private camping development consisting of approximately 50 trailers and attendent facilities and a gun club facility including a clubhouse, target range, and a one-half acre pond, just north of Winchendon Road.

If implemented, the 400 acre site will be cleared and seasonally inundated, including all of Priest Brook above the proposed damsite, and short reaches of Scott and Town Brooks. The entire project area will be subject to periodic inundation and drawdown. During certain times of the year, natural stream flow into the Millers River would be reduced.

(c) Tully Reservoir Diversion

The East Branch Tully River extends about 15 miles from its headwaters in southern New Hampshire to its confluence with the West Branch Tully River. Open waters along the stream, including Tully Reservoir, cover 6 miles. The total drainage area of this river is 56 square miles of which about 8 are wetland, 6 are open water, and the rest upland habitat.

The river is of medium gradient with a section of slow moving water in the Long Pond area. Width varies up to 30 feet and depth up to 8 feet in some areas. Water quality is good (Class B) and is classified as "good trout water" on a seasonal basis. Terrain surrounding the river is moderately steep and heavily forested with mixed deciduous and coniferous trees.

The East Branch of the Tully River is stocked annually with trout by the Massachusetts Division of Fisheries and Game which provides a "put-and-take" sport fishery. Waterfowl and other game species are typical of those found in the Tarbell and Priest Brook Watersheds. Considerable hunting activity for birds, small animals, and deer takes place in the basin. Numerous wood roads and trails remaining from past logging operations provide good access for hunters and fishermen. Recreation development potential is excellent and good white-water canoeing occurs below Tully Dam during periods of high water.

The proposed diversion site would be located within the existing Tully flood control reservoir. The existing pool forming Tully Lake would be doubled, increasing the present surface area to 620 acres during the summer recreation season. The pool would subsequently be gradually drawn down after Labor Day. Since Tully Lake would become a domestic water supply source, it appears necessary to clear and strip organic material on the bottom in order to protect the water quality.

With the proposed plan of diversion from Tully Reservoir to Quabbin, up to 25 percent of the storage capacity of Tully will be used for the dual purpose of flood control and water supply. During the spring freshet season, this storage will be filled if, and when, inflows exceed downstream requirements and diversion capacity. This stored water will later be diverted to Quabbin, making the full flood control storage capacity of Tully available for the fall hurricane season.

Flood control storage requirements are the greatest in southern New England during the fall hurricane season and secondly in the spring during the snowmelt season. The filling of the multi-purpose storage during the spring high flow periods may provide incidental flood control. Analysis of streamflow records indicate that less flood control storage is required during the summer season than the rest of the year for comparable degree of protection. As a result, in some Corps reservoirs in New England, some seasonal encroachment on flood control storage has been recommended for other worthwhile uses.

(d) West Branch Tully River Diversion

The West Branch Tully River, including Tully Brook, north of Sheomet Lake, is about 8 miles long, extending from its headwaters in central northern Massachusetts to its confluence with the East Branch Tully River, 1-1/2 miles north of Athol. The West Branch is of a moderate gradient, and is up to 35 feet wide with depths up to 5 feet along its course. Open water areas, mainly Sheomet Lake, cover only 1/2 mile along the river. Water quality is good (Class B) and the river is annually stocked with trout by the Massachusetts Division of Fisheries and Game. Total drainage area of the basin is about 19 square miles of which approximately 2 acres are wetland and the remainder upland.

The river flows through a relatively unpopulated and heavily wooded (mixed conifer and deciduous) area. Wildlife found in this basin is similar to that of the nearby East Branch Tully, Priest, and Tarbell Brook areas.

The proposed diversion site would be located two miles north of Athol, in the town of Orange. It would be on the West Branch Tully River about 500 feet above the confluence with the East Branch Tully River, and about 1-1/2 miles above the confluence with the Millers River.

(2) Losses From Land Inundated by Impoundments

(a) Tarbell - The seasonal pool would periodically inundate 40 acres of wildlife habitat including 1/2 mile of free flowing stream. The 5-foot high weir would prevent free movement of stocked well as resident fishes.

(b) Priest Brook - The 400 acres inundated seasonally by this project are comprised of 330 acres of wetland and 70 acres of upland habitat. Reservoir storage would be evacuated as soon as possible to Quabbin Reservoir.

(c) East Branch Tully - About 300 acres of wetland behind the existing Tully Dam would become subject to periodic flooding should Alternative No. 3 be implemented. This land is presently subject to seasonal inundation during natural flood conditions. Following fall drawdown, 300 additional acres of lake bottom would become exposed.

(d) West Branch Tully Pool - A small diversion pool would inundate about 13 acres of upland game habitat.

(3) <u>Reduction in Flow Caused by Diversion</u>

Tarbell Brook, Priest Brook, East Branch Tully River and West Branch Tully River - The reduction in flow in these streams would, of course, reduce scouring from high spring flows; however, all these streams are relatively unpolluted and bottom deposits are not expected to cause any problems. Reduced flows from these streams, as described earlier, however, would cause lower river stages on the Millers during spring high flow periods.

(4) <u>Impacts From Impoundments</u>

Intakes on Tarbell Brook, Priest Brook and West Branch Tully River - These structures would create little aesthetic damage. They would, however, prevent the free movement of stocked as well as resident fishes. During construction, some silting of the streams would be evident; however, cofferdams could be employed to keep silting to a minimum.

Impoundments to be formed by the construction and operation for diversion in this alternative will vary in area and duration of water storage. Tarbell Brook would impound a 40-acre pool with a maximum depth of 9 feet and an average depth of 5 feet.

Priest Brook dam would impound water in a temporary reservoir, filling only when the combined flow of Priest Brook and diverted flow from Tarbell Brook exceed 120 cfs. When filled, the pool would cover 400 acres with a maximum depth of 25 feet. During operations, the pool would be subject to periodic fluctuations. After the diversion period, the pool would be empty.

Tully Dam, in Alternative No. 3, would be operated in a manner similar to that of Priest Brook. During the diversion period, the 620 acre pool would be subjected to wide fluctuations in reservoir area and volume. During summer periods, a recreation pool would be established and no diversions would occur.

West Branch Tully River Dam would be similar to the Tarbell Brook installation. At this site, a 13 acre pool would be maintained and only nominal fluctuations in water levels and pool area would occur.

The shallow nature of the various impoundments such as those proposed for the tributary streams in this alternative tend to reduce the quality of the water impounded in them. Water temperatures are increased, algal populations may increase, and dissolved oxygen concentrations may decrease. In recognition of this potential, the stripping of organic material from the Priest and Tully sites was considered necessary.

6) Possible Environmental Impacts of Diversion on Quabbin Reservoir

This study generated and evaluated extensive data on the Quabbin and Wachusett Reservoirs and the Connecticut and Millers Rivers Systems, with the objective of making predictions on the impacts of diverting portions of these riverine systems into Quabbin Reservoir. Field and laboratory data included approximately 100 parameters, including chemical, physical, biological, and pesticides data. In addition, radiological data, hydrodynamic studies, fisheries information, and pollution abatement plans were considered and evaluated. Finally, other pertinent data available from both public and private sources, especially on the Connecticut River, were evaluated in the light of the objectives of this study. A summary of this evaluation is given in the following sections. A complete description of the study results is given in Appendix I.

Central to the evaluation was the development of a qualitative model of reservoir dynamics. If water of lower quality is introduced from a river system into a receiver system, there will most likely be a loss in water quality in the receiver system. This loss of water quality is due to various materials in the water. These materials include molecules, ions, suspended inorganic materials, organic debris, and living organisms. One of the central problems of ecology today is to trace the flow of materials from the various compartments of an eco-system.

A major difficulty in evaluating and describing impacts on water quality and ecology which would occur with either Alternative No. 1 or No. 2 is the present water quality of the Millers River. As it presently exists, the Millers River water quality is not suitable for diversion as a water supply source. The inclusion of potential diversions from the Millers as an alternative, therefore, is based on anticipated water quality not existing.

This higher quality water is expected following implementation of planned state-federal pollution abatement program and the advanced waste treatment facilities proposed as part of the water supply plans. Since the proposed waste treatment plants would employ a high level of treatment efficiency on pollutants being discharged to the Millers River, a return of the river to its natural background quality could be expected.

As part of the water quality monitoring network established for this report, five stations were sampled on five northern tributaries of the Millers. These tributaries are sparsely settled and not subject to waste discharges. Data collected in the tributaries, therefore, is considered to portray natural background water quality conditions.

The watershed of the various upstream tributaries is a significant proportion of the Millers River drainage area at the diversion intake.

Thus, utilization of upstream tributary data to indicate background water quality in the Millers River after clean-up seems reasonable. Using this approach, a summary of possible impacts of the proposed diversions in Quabbin Reservoir was prepared. These impacts are illustrated in Table 28. A complete description of all possible impacts is given in Appendix I.

7) Possible Environmental Impact Caused by Added Waste Load of Receivers

In keeping with the objectives of the Environmental Quality account, the impact which added waste loads, occassioned by the additional water supply, from the project was also investigated. To provide a measure of the added waste load impact, it was assumed that the environmental cost would be considered as the cost of bringing the quality of water back to its original state. It must also be recognized that a supply deficit already exists. Total added waste treatment required is then

TABLE 28

SUMMARY OF POSSIBLE IMPACTS OF THE PROPOSED DIVERSIONS ON QUABBIN RESERVOIR

NOTE: This summary does not predict the duration of the impact.

Description of Impact	Relative Probability Impact Will Occur			
	No significant change over existing conditions	Possible but Probability Low	Probable	Probability High
Increase in Nutrient Chemicals		X		
Increase in Eutrophication		X		
Modification of Present Equili-bration			X	
Introduction of Undesirable Species		X		
Increase in Coliform Bacteria		X		
Increase in Human Pathogens		X		
Interference with Water Treatment at Quabbin		X		
Increase in Levels of Toxic Materials	X			
Increase in Levels of Radioactivity	X			
Increase in Levels of Pesticides	X			
Increase in Extent and Magnitude of Oxygen Depletion		X		

equal to the time for demand to increase to the level allowed by the increased yield.

Estimates of providing advanced waste treatment to the incremental water supplied was made. It was assumed that 70% of this additional supply would be treated; the remaining 30% would be lost from the system through evaporation, irrigation and consumed process water. The estimated costs of providing the necessary treatment is 2.3 million dollars on an average annual basis.

Care should be exercised by the reader, however, in translating this treatment cost dollar total to the earlier Regional Development and National Economic Development Accounts analysis. Offsetting the costs in general of this additional treatment required is the revenue lost to the MDC system if additional supply is not made available. For example, at present, water rates ($200/mg) revenue lost (or not available) without additional supplies totals 3.5 million dollars on an average annual basis.

In an attempt to preclude confusion by the reader in the Regional Development or the National Economic Development Accounts, neither the added waste treatment costs nor the benefit derived by the system in selling the added water were included. Thus, the two earlier account assessments are in essence addressed to an examination of net costs and net benefits.

8) <u>Possible Environmental Impacts Caused by Construction of the Alternative Projects</u>

The planning phase design of the aqueducts and appurtenant structures of the three alternative projects precludes a detailed assessment of possible environmental impacts associated with the construction phase. If authorized, the recommended project would undergo detailed design which could alter the preliminary design presented in this report. For example, tunnel shaft locations selected in this report may change, which in turn would affect possible environmental impacts of such construction activities as tunnel spoil disposal, selection of haul roads and maintenance areas.

In response to the possible alterations in design and other followup action which might affect the environment, the Corps of Engineers requires four environmental impact statements for each project authorized. These separate statements are prepared for the Planning, Design and Construction phases and finally for the Operations and Maintenance stage.

This interim report of survey is a planning stage report. Detailed data, therefore, are not available on all environmental impacts which might be encountered during final design and construction of the project. Sufficient information is available, however, to highlight possible areas of environmental concern which would be considered in the followup phases.

All work on the tunnels in the alternative projects would be underground. Thus, the majority of this construction activity would not be visible or disrupting to the environment. Since the majority of the tunnel routes is in rock of good tunneling quality, the possibility of disrupting local ground water supplies is low. However, the Northfield Mountain hydroelectric facility recently constructed in the region experienced some limited disruption of individual supplies. Therefore, this possibility should be assessed when the final route is selected.

Total rock spoil from tunnel construction of the alternatives is estimated to range from 97,000 cubic yards to 243,000 cubic yards. In the preliminary design, these quantities would require about 2 to 5 acres with a 30 foot depth. Spoil from the tunnel, however, is expected to be of good quality and some or all of the material may be recycled into other local construction projects such as road construction. This potential for recycling would depend on final design and other construction activities under way in the vicinity.

Surface construction activities of the tunnels are expected to be limited to the vicinity of the construction shafts and connecting haul roads to spoil areas if needed. Environmental impacts which should be considered in the followup phases include impact on maintenance areas, haul trucks and other associated construction needs.

Alternative No. 3 in addition to tunnels includes as facilities connecting conduits between the various tributaries. These connecting pipelines would be cut and cover conduits and thus would require temporary surface disruption. To minimize any possible disruption, pipeline routes were located mostly within existing highway and power rights of way.

In summary, detailed environmental impacts of the construction activities associated with the alternative projects cannot be fully described during the planning phase. Possible impacts, however, would be fully described in followup environmental studies conducted in the design, construction and operation and maintenance stages. Although all possible impacts cannot be quantified at this time, sufficient data exists which indicates no major adverse effects from the recommended project. This conclusion is based primarily on the fact that the majority of construction activities would be underground. Surface construction activities may have potential impacts, but experience with similar projects indicates such impacts can be minimized through careful planning in the design and construction phases.

9) Possible Environmental Quality Enhancement

a) Environmental Health of Quabbin Reservoir

Environmental health of Quabbin Reservoir is presently in danger. Since 1970, water demands upon the Quabbin system have exceeded the safe yield of the Quabbin watershed. This means that on a long term runoff basis, volume and level of Quabbin will decrease until existing inflows are augmented with new sources even though 1972 and the winter of 1972-1973 were excessively "wet years" and reservoir levels rose significantly.

Water quality conditions, algal growth patterns in the northern portions of Quabbin suggest that progression toward eutrophication is already taking place there. Water quality in the main body of the reservoir is still of a high quality, but if volumes decrease as projected over the years, the relative masses of high, versus low, quality water will shift toward an overall loss in water quality. Losses in volume will decrease the natural purification or "treatment plant" capacity and possibly the retention times of inflow waters. Losses in the hypolimnion volume could diminish the managed standing crop of salmonid fishes. The depletion of oxygen in the hypolimnion whether partial or complete depends a great deal on quantities of reducing agents in the water. Potential impacts on water quality are manyfold. Iron and manganese may be reduced to the ferrous and manganous state and released to the water column. Sulfate may be reduced to hydrogen sulfide gas resulting in obnoxious gas. In general, then, Quabbin may become unacceptable as a water supply source.

When the waters from the recommended project are introduced into the system, the yields of the system will again exceed the demand and levels of Quabbin will increase. With careful management and monitoring, eutrophication can be arrested and the reservoir will continue as a highly acceptable water supply source.

b) Environmental Health in Receiver Communities

Environmental health in the communities to be serviced by the project would undoubtedly suffer without project implementation. Much has been stated previously of the economic and socio-economic impacts in the receiver area which would accompany construction of the project. Almost without exception these impacts were of a positive nature, maintaining past progress in improving the quality of life. In addition to these economic and socio-economic gains in the receiver area, construction of the project should provide beneficial environmental impacts as well.

Thus, the impact on the environment caused by the recommended project can be viewed from two perspectives. First are those impacts on the estuary, Connecticut and Millers Rivers and the receiving water bodies which would be caused by project implementation. The second perspective is the environmental impacts which would be prevented by project construction. In all cases, possible changes brought about by the recommended project must be viewed in light of the environmental damage which could be expected without the project. Utilizing this approach, it appears that environmental impacts expected with the recommended project implementation are less than could be expected without the project.

SECTION X

PREFERRED PLAN - MILLERS RIVER BASIN DIVERSION ALTERNATIVES

26. General

As described in the preceding sections, three methods of developing the resources of the Millers River Basin were investigated:

Alternative No. 1 - Millers River
Alternative No. 2 - Tully-Millers River
Alternative No. 3 - Tully Complex

The existing storage capacity at Quabbin Reservoir was intentionally constructed larger than the natural drainage area requires. Thus, excess storage capacity is available within the reservoir. In lieu of developing additional reservoirs within the Millers River Basin, all three alternatives examined would utilize the existing storage potential by means of a high flow withdrawal technique.

27. Alternative No. 1 - Millers River

In this plan, water would be diverted during high flow periods from the Millers River to Quabbin Reservoir. At present, however, the Millers River is heavily polluted. In order to provide acceptable water quality, therefore, waste treatment facilities are necessary. Present planning by Federal and State pollution control agencies requires the construction and operation of secondary waste treatment plants by 1976. Based on this report's analysis, additional facilities beyond those presently planned are necessary to insure suitable quality water. Therefore, this alternative includes the provision of additional treatment processes as part of the project's elements.

For both the Regional Development and National Economic Development Objectives, this plan offers a cost effective means of meeting present needs. As presented in Table 29, the benefit/cost ratio for this project is slightly higher than Alternative No. 2, and substantially higher than No. 3.

TABLE 29

BENEFIT/COST RATIO
ALTERNATIVE DIVERSION PROJECTS

	Regional Development Objective		National Economic Development Objective	
	Normal Runoff	Sixties Drought Runoff	Normal Runoff	Sixties Drought Runoff
Alternative No. 1	1.3	2.0	1.1	1.8
Alternative No. 2	1.2	1.8	1.1	1.6
Alternative No. 3	1.0	1.5	0.9	1.4

In the Environmental Quality Account, development of this plan could cause impacts on the Millers and Connecticut Rivers and the Connecticut River Estuary which can be characterized as minor. Inclusion of the additional waste treatment facilities would result in better quality water than possible under the existing planned program.

On the basis of the three account system evaluation, Alternative No. 1 was considered a viable candidate for meeting short term needs. However, the reliability of water quality within the Millers River is subject to a number of questions.

Will existing sludge deposits within the river be a factor in water quality at the scheduled date for use of the river? Sampling data indicates the existing sludge contains trace metals such as mercury and cadmium, both of which are injurious to health.

What influence would non-point sources of pollution, e.g., abandoned dumps, urban runoff, etc., have on the water quality?

Advanced waste treatment facilities actually in operation are limited; and although experience to date has been favorable, can it be said with reliability that the plants would always be performing to full expectation at the time diversions are needed?

Answers to such questions are speculative without the benefit of actually observing the river's natural reaction to a "clean-up" program. It is conceivable that if this alternative was chosen and work undertaken, the river may not be suitable for delivery to Quabbin Reservoir when needed. Additional work would then be needed to improve the water quality and insure its acceptability as a water supply source. Delays in providing the needed supply to communities would result. The potential for these delays argues against the timeliness of this alternative.

In an attempt to answer whether, in fact, it could be guaranteed that the river would be suitable for diversion as a water supply source when needed, both State and Federal Public Health authorities were consulted. In correspondence directed to the Massachusetts Department of Public Health, the question was asked:

> "Would the responsible State Agencies, including the Public Health Department, agree that diversions from the Millers River itself could be accomplished without actual observation of the river's natural reaction to pollution abatement and resulting water quality?"

Their response to this question, in part, reads:

> "Plans and proposals for the eventual construction of municipal and industrial waste treatment plants, degree of treatment, effectiveness of treatment and operational problems are all areas subject to so many variables that the Department is unwilling to speculate on the hypothetical premise of the suitability of this supply under any given set of conditions."

Since no guarantee can be given that water would be available when needed, the timeliness and reliability of this plan were considered in the evaluation of all alternatives.

A second key factor in the assessment of this project was the protection of Quabbin Reservoir's environmental health. As described in earlier sections, biological studies have determined that large drawdowns of Quabbin would significantly affect the present ecology of that large water body. Any major reduction in ecological viability would, in turn, considerably diminish the fishing and recreation opportunities at the reservoir. Protection of the reservoir will be increased when additional yield is made available. Such additions, however, would be required in a timely fashion. Therefore, the reliability and timeliness which Alternative No. 1 presents with respect to preserving Quabbin were other elements in this plan's evaluation and were major criteria which ultimately led to the selection of another alternative plan.

28. Alternative No. 2 - Tully-Millers Rivers

This plan would divert water during high flow periods from two locations in the Millers River Basin, the Millers River itself, and a tributary, the East Branch of the Tully River.

In both the Regional Development and National Economic Development Objective accounts, Alternative No. 2 ranks slightly lower than the plan which develops only Millers River water. As presented in Table 29, however, the benefit/cost ratios for both alternative plans are essentially similar.

In the Environmental Quality Account, impacts on the Millers and Connecticut Rivers and the Connecticut River Estuary would be similar for both Alternatives No. 1 and 2. Additional impacts which could occur with this plan would be on the Tully River downstream to the Millers River, a distance of 4 miles; Although, based on the investigations conducted, no major impacts are forecast for this reach of the river.

A casual examination of the two plans might not reveal any major choices between the two. There is, however, a major difference between the two, as Alternative No. 2 would utilize flow from the East Branch of the Tully River as feeder water for Quabbin Reservoir. With regard to water quality, the East Branch Tully River is presently suitable for diversion to Quabbin Reservoir as a supply source, while the Millers River is not. Because of the availability of the good quality Tully River water, the reliability of this plan is increased considerably. The risk described regarding use of the Millers River in Plan No. 1 in turn is decreased. In essence, use of the Tully River, which can deliver 24 million gallons per day of supply, "buys time" in which results of the proposed waste treatment facilities can be observed, monitored and evaluated.

Use of the Tully River water as part of this plan also acts to insure adequate water supplies for communities. Since it can be said with assurance that the Tully water can be delivered on time, the question on timeliness which surrounded Alternative No. 1 is diminished.

The dual intake location afforded by this plan offers a large degree of flexibility in the operation phase. If, for example, a potential health hazard was detected in the Millers River, diversions could still continue from the Tully River. By operational scheduling, existing flood control dams and the diversion structures could act to enhance existing flood protection.

Another major element which must be considered with respect to Alternative No. 2 is the increased protection it affords to the environmental health of Quabbin. Tully River water, based on studies conducted, is compatible with that of the reservoir. Therefore, no risk is involved with the immediate diversion of this water. Implementation of the proposed Millers River waste treatment facilities will, of course, decrease any risk associated with diversion of that water to Quabbin. However, a period of testing and observation of the Millers River natural reaction to treatment before volumes of this water are introduced to the reservoir is desirable. Alternative No. 2, with the availability of the good quality Tully water, acts to provide a safety factor.

29. Alternative No. 3 - Tully Complex

Owing to the questions regarding use of the Millers River mainstem, the NEWS Study also investigated the potential which diversions from cleaner tributaries might have. Based on analysis of data, the existing quality of some of these tributaries was found to be suitable for use as a supply source. In addition, the water quality is expected to blend well with Quabbin Reservoir water; and therefore, no predictable environmental damage would occur in the reservoir.

For both the Regional Development and National Economic Development Objectives, however, Alternative No. 3 would yield the lowest benefit/cost ratio. As shown in Table 29, this plan was the lowest of the three with regard to cost effectiveness.

From the viewpoint of the Environmental Quality Objective, possible environmental impacts on source streams for Plan No. 3 could be greater than with either Alternative No. 1 or No. 2. Impoundments would be required on the various tributaries and some stream reaches would be seasonally inundated.

Changes in water quality within the local areas of impoundments are forecast and a general change in the ecology of the impoundments is anticipated. Land taking requirements for this plan are the largest of the alternatives (1,103 acres compared to 40 acres for No. 1 and No. 2), and public input to the planning process was generally negative to this scheme.

The major advantage of this plan is the known good quality water; and with existing conditions, this water can be transferred to Quabbin Reservoir with minimal potential public health or environmental damage. The Tully Complex Diversion facilities could be constructed without the speculative questions which are inherent with Alternative No. 1 and the Millers River portion of Alternative No. 2, and the communities in need of water would be assured adequate supply.

But disadvantages to Alternative No. 3 are several. The plan is the most expensive from an economic viewpoint, and its potential yield is less than either Alternative No. 1 or No. 2. Socio-economic impacts are larger with Alternative No. 3 than the other two plans. Finally, possible environmental impacts within the Millers River Basin are greater than with Alternative No. 1 or No. 2.

30. Summary - Millers River Basin Diversion Alternatives

On the basis of the investigations conducted in this study on the three Millers River Basin Diversion Alternatives; namely,

Alternative No. 1	Millers River Diversion
Alternative No. 2	Tully-Millers River Diversion
Alternative No. 3	Tully Complex Diversion

the most advantageous plan for both the communities within the source area as well as those municipalities which would use the water is Alternative No. 2. Some of the advantages of this plan include:

1) This project's economic costs are fully competitive with the other alternatives. (See Table 29)

2) This plan provides for a larger multiple use prospect and a cleanup of the Millers River would be beneficial to communities in the Basin. A clean river water, even after diversion, would provide an opportunity for use of the river for water supply, recreation, fishing and other outdoor activities long denied because of the river's pollution.

Cleanup of the river includes advance wastewater (tertiary) treatment at pollution sources, providing a river of higher quality than is presently anticipated, even after the planned secondary treatment program is implemented.

3) Yield for water supply purposes could be greater than Alternative No. 1 or 3, and would consequently meet needs of serviced municipalities through a longer time frame.

4) Any possible environmental damage to the river should be largely offset by the river cleanup program along with the opportunities for environmental enhancement which presently do not exist.

5) Use of the East Branch Tully River water as part of the project would minimize the "risk" that the mainstem water, even after cleanup, because of the river's natural reaction, may not be available when needed. East Branch Tully River water will allow adequate time for testing, monitoring and evaluation of the Millers River water prior to its diversion.

6) Land requirements for necessary facilities and changes in land use patterns caused by the project are held to a minimum. About 40 acres of land would be required for the Millers intake and tunnel shafts, beyond that the land required is already in public ownership. There is a possibility that an additional 5 acres for rock excavated from the tunnel may be necessary; but such need would be a detailed design consideration.

7) Major negative socio-economic impacts forecast for the municipalities to be serviced by the diversion will be avoided.

8) Natural flows in tributary streams, except East Branch Tully, as well as the Millers River upstream of the diversion intake in Athol, will not be altered.

SECTION XI

OTHER ALTERNATIVES

31. General

In this report, a wide range of alternatives to the Millers River Basin - Alternative No. 2 was investigated. Included in these alternatives were other possible diversions, use of new technology as a means of augmenting existing supplies, non-structural approaches such as reduction of demand and the evaluation of the no-action alternative. A description of these alternatives and their potential as solutions to the existing problem, are given in the following paragraphs.

32. No Action

In the evaluation of this alternative, it was assumed that any failure to secure timely additional supplies for the service area will result in major economic and social losses to the entire planning region. To verify this assumption, a quantification of these impacts was necessary.

Estimates of impacts caused by a no-action policy can be expressed in two different ways. First, concrete losses without the diversion total $96 million to 1990 and $528 million to 2020, if average runoff conditions prevailed. Under drought conditions, concrete losses without diversion total $201 million to 1990 and $623 million to 2020.

As described in the previous section and Appendix K, categories included in these totals encompass industrial, city emergency, city revenue: commerce, sprinkling, business investment and domestic investment losses. However, economic losses in these categories say nothing of the ways in which the losses might be allocated. For example, of the approximately $3.5 million not collected in city revenue in 1990 by all receivers under a no-action policy, there is no way of knowing with certainty whether it would be municipal expenditures on recreation or schools that might suffer. In Section IX, this loss in revenue was expressed as 600 classrooms. Similarly, housing units not built are but an alternative manifestation of losses in the private sector.

Social impacts in communities serviced by the supply system under a no-action alternative would be principally "shadow costs" of the concrete losses. To assess the impacts of such shadow costs on the sixty-six receiver communities, the experience of an actual municipality already beset by the kinds of problems anticipated in the event of prolonged water shortage was evaluated.

The town selected for examination was Stoughton, Massachusetts, an industrial - residential community in the Brockton S. M. S. A. An extended interview with Stoughton's Planning Board Chairman produced both background and impact information. Growth in the town has been steadily upward and shows no sign of a downward turn. The principal constraint on continuing growth may be an acute shortage of water.

The town has been searching for water since 1955 and results have been disappointing. The consequences of the resulting water deprivation have been felt across a wide range of community activities.

Although no shifts in the allocations of land use type have occurred, development in the industrial category has been nearly stopped by water shortage. Economic development has been hurt because water using industries have been turned away. This has slightly decreased the stability of the town because the tax base has not expanded quickly enough to keep up with the demands on local revenue. Wages and prices have remained in phase with the rest of the state, but taxes have increased. No Stoughton industries have left because of water shortage, but new industries have gone elsewhere. Presently, only non-manufacturing, non-processing firms are permitted to locate in town, and a $40 million industrial park is now two years behind in its development schedule.

While data projections estimated in this report show population deficits without the provision of additional supply, it does not appear, based on the Stoughton experience, that population growth is sensitive to short term controls and constraints. Stoughton's in-migration continued despite the building ban and shows signs of growing even more quickly now that new housing construction has begun again. Since the lifting of the building ban, over 500 rental units have been built and occupied. The demand for housing has lowered the vacancy rates significantly and stimulated the construction of 3,000 apartment units and the planned development of 3,000 more. Before the ban went into effect, issuances of building permits had declined for two successive years.

Because finding water has been a top town priority, other municipal services have suffered. A sidewalk program has been indefinitely postponed, and only minimal roadway maintenance and construction have occurred. Generally, expenditures have been cut as revenues from expected property tax have dwindled. Estimates range as high as $1,000,000 in tax losses with increases in assessments covering the deficit. The cost of water has doubled in the past two years, and the municipal debt as of 1 January 1970 stood at $320 per capita. Until a mutual help agreement was reached with Easton and Sharon, adequate fire protection was a critical concern. A much needed junior high school has been put off -- an effect attributed to the "extraordinary high expenditures of finding water." As a result, the present junior high is now in double sessions.

As the search for water has become business as usual, citizens appear to have developed some tolerances for the inconvenience of watering bans. However, their latent insecurity about adequate supplies for fire protection and general domestic consumption have made water shortage a perennial political issue on which concern can focus.

Despite the general slowdown in industrial development and its second order consequences on town revenues, the average citizen perceives the water supply problem in terms of his own inability to water outdoors. Lawns and shrubbery are a waste of money, says the homeowner, and the town looks poorer for it. In turn, these feelings are reflected in attitudes about the desirability of the community as a place to live and work.

In addition to socio-economic impacts, a second major impact could occur with the no-action alternative. This second impact regards the probable deterioration in water quality within Quabbin Reservoir which could be caused by lowered reservoir volumes. As described in Section IX, Quabbin Reservoir presents a complex limnological situation. Some areas of the reservoir such as the northern sections appear to be progressing toward eutrophication. In the main reservoir body, however, quality is still high. If the pool volume decreases over the years as would occur with the no-action alternative, then there will be a shift towards an overall loss in water quality in the reservoir. Losses in volume will decrease the "treatment plant" capacity and hypolimnion volumes affecting water quality from both an environmental and public health standpoint.

Based on the evaluation of the socio-economic and environmental impacts, the no-action alternative has many disadvantages. Use of this alternative, therefore, does not offer a realistic solution to the short range needs of the study area.

33. Weather Modification

The primary source of the water used for public and private water supply in Massachusetts, as in most humid areas, is precipitation falling directly on the areas concerned. It follows then that if precipitation can be increased in a regulated manner, the water supply can also be increased. To this end, several major agencies such as the National Oceanic and Atmospheric Administration (NOAA), the United States Bureau of Reclamation, the American Meteorological Society, and the National Science Foundation are investigating ways of productively modifying natural precipitation patterns. The primary focus of research is in the area of cloud seeding. Other fields of interest are long-term seasonal precipitation forecasting and fog drip augmentation. Since little work has been done on the latter two, and what little has been accomplished is not applicable to the Massachusetts area, only the process of cloud seeding will be reviewed in this section.

A. Cloud Seeding

Simply stated, rain falls from clouds when water vapor in the clouds condenses around nuclei and forms rain drops large enough to overcome frictional resistance to falling. In technical terms, this process is the conversion of the water vapor from a state of colloidal stability to one of colloidal instability. The concept of artificially induced precipitation by cloud seeding refers to the introduction of particles of foreign substances, such as dry ice and silver iodide into clouds to serve as condensation nuclei. Theoretically, this action will result in condensation of the water vapor and consequent precipitation. In short, it is scientific rain making.

The testing of the engineering and economic feasibility of this theoretical process has been concentrated in experimental projects in the Rocky Mountain and Upper Great Plains regions. Evidence gained through NOAA research suggests that winter cloud systems over Lake Erie may be modified to produce additional precipitation. A cost benefit study was performed for the Connecticut River Basin, but this study was in design only with no actual experimental work involved. Most information regarding the potential of cloud seeding in the eastern United States is derived from commercial cloud seeding operations.

Some of the findings resulting from these studies and experiments are summarized below:

1) The state of the art is such that most researchers look upon the potential of increased precipitation through cloud seeding with

an air of cautious optimism. Study to date, however, has provided little more than a beginning to the solution of many of the problems involved in weather modification.

2) Cloud seeding is impractical during severe drought conditions when water shortages are most critical. The first requisite for cloud seeding is the presence of clouds, and droughts are notable for their lack of clouds. Present technology is not even remotely capable of producing clouds by weather pattern modification. During a temporary interruption of drought conditions, clouds may form over an area. Even under these conditions, however, cloud seeding would not appreciably alleviate water supply problems since most precipitation would be in all likelihood taken up immediately by plants and soil. It is apparent then that water shortages in periods of drought cannot be solved by cloud seeding. Any substantial seeding induced precipitation would have to be produced during non-drought conditions with abundant moisture in the atmosphere.

3) There are many problems that must be solved before substantial technological breakthroughs result. One of the most critical is the inability of researchers to satisfactorily define optimum cloud conditions and seeding techniques and to predict seeding results accurately. In other words, there is an inadequate understanding of the basic cloud processes which determine: a) the "seedability" of a cloud or cloud system, and b) the proper seeding treatment to stimulate rainfall production efficiently in a potentially seedable cloud.

Another problem is the possibility of undesirable effects of seeding. Indiscriminate seeding might increase soil erosion and sedimentation in streams through intensification of the normal rainfall rate of natural storms. There is the possibility also that artificial seeding of clouds might in fact reduce the natural rain producing capacity of the clouds.

4) Estimates of the feasibility of cloud seeding in the eastern part of the country, including New England, are vague and poorly defined. Most recent cloud seeding research has been conducted in the western states. Atmospheric scientists have cautioned that results of seeding experiments in one area of the country must be viewed with caution when applied to other areas characterized by different topography and climate. It is apparent that much research needs to be done in the eastern part of the country. There is data available for parts of this area from commercial cloud seeding operations. However, these operations were not performed under proper scientific and statistical control procedures and any data gathered in such a manner must be used and interpreted with care.

B. Conclusion

Research has continued to improve the state of the art of weather modification by cloud seeding and other means. At best, however, weather modification is still an inexact science. Studies are unable to predict optimum cloud conditions and seeding results with any degree of accuracy. It is the conclusion of this section, therefore, that at this time weather modification operations to augment water supplies in Massachusetts does not appear to be a viable solution to the immediate water supply problem.

34. Desalinization

Desalinization, the process in which brackish and salt water is converted to fresh, is currently being used in some parts of the world as a viable, economically feasible source of fresh water. This process thus was considered for its potential as a future alternative solution to the water supply needs of eastern Massachusetts.

The conversion of saline to fresh water is accomplished through four major processes: distillation-evaporation, membrane separation, crystallization, and chemical differentiation. A descriptive summary of each process is given below.

A. Distillation-Evaporation

In this process, water containing salt or other impurities is heated and vaporized. The water vapor, free from the salt and other solids which remain behind as the water boils, is then condensed and collected. The system is basically a simple one requiring only a source of heat energy to boil the water, a method of cooling the water vapor (condensation) and various kinds of plumbing and receptacles for the transfer and storage of the water.

Since distillation, by its nature, results in the complete separation of the water vapor from the dissolved salts of the influent, the process produces fresh water of exceptional purity. Because this method removes the water from the salt, rather than vice versa, the quality of the influent is not critical and the system works equally well on water with a high salt content as an only slightly brackish water. For these reasons, among others, distillation is the oldest and best-known process of desalinization.

B. Membrane Separation

Desalinization by the membrane process is based upon the ability of thin membranes to pass molecule of pure water and retain the ions of salts and other dissolved solids. There are three basic variations to this concept: a) electrodialysis, b) transport depletion, and c) reverse osmosis. The first two variations depend on the electrical properties of the ions involved, while the third depends on a pressure differential existing across the membrane. Of these three variations, the electrodialysis process is the most well established, with many commercial installations throughout the world.

In contrast to distillation, the membrane process separates the salt from the water rather than the water from the salt. Each stage of the electrodialysis process removes slightly less than 50% of the dissolved solids in the water being treated. The more saline water, the more stages are needed and hence more energy is consumed. For this reason, electrodialysis and other variations of the membrane process are more economical when used with brackish water with a salinity of between 5,000 - 10,000 mg/l, as opposed to more saline water. The water can then be refined in stages to the desired degree of purity.

C. Crystallization

This process relies primarily upon the fact that as water freezes, the ice crystals reject ions of salt. Saline water is frozen and the crystals of pure ice are then skimmed or removed for later use from the still liquid brine. A second method of separation by crystallization employs the hydrate process which is the formation of a crystalline substance by the combination of water with low molecular weight, hydrocarbons or their derivatives. Like ice crystals, these hydrates reject salt ions. It takes less energy to freeze water than it does to boil it, thus this method has an advantage over distillation in that it consumes less energy. The crystallization process has not been widely used, however, and further research into its effectiveness is continuing.

D. Chemical

In this process either the water or the dissolved salts are made to undergo a chemical reaction which forms a substance which can be easily separated from the untreated water. Ion exchange, a method by which the saline water is passed through treated resin and the salt ions selectively removed, is the most widely used method of chemical desalinization.

The efficiency of ion exchange decreases with time as the "holes" in the resin become filled with salt ions. Once the resin is saturated, the operation must be closed down and the resin regenerated. For these reasons, the process has had only local exposure and small volume use.

E. Present Application

Sea water can be considered, for all intents and purposes, an unlimited source of fresh water once the technology of desalinization is refined to a point where it is economically feasible. To this purpose, the federal government, through the Office of Saline Water, has promoted extensive study and research into the problems of desalinization. Several model and testing plants and facilities have been constructed to aid in these studies. The research to date concludes that of the four main processes discussed above, distillation and membrane separation are best suited to large capacity plants. Economical considerations dictate that distillation is best for sea water and electrodialysis for brackish water.

Presently more than 300 million gallons per day (mgd) of desalting capacity is installed world-wide. Plants are generally located in arid regions where conventional water sources are high cost or unavailable. Principal areas of use are in the Mid-East and Caribbean tourist islands. In the United States, desalting for municipal water supply has thus far been limited to smaller communities, relatively isolated from sources of conventional supply.

The largest municipal desalting plant in the United States is a 2.6 mgd distillation process in Key West, Florida. Largest in the world is a French-built, 30 mgd distillation plant, recently completed in Kuwait.

A distillation plant was recently proposed for San Louis Obispo and Santa Barbara Counties, California, which would have a capacity of 40 mgd. Construction on this plant which would have been the largest in the world was scheduled to begin in 1973, however, action on this plant has been recently suspended.

F. Costs of Desalinization

The cost of fresh water produced by desalinization depends upon the capacity of the plant, the type of process used and whether nuclear or fossis fuel is used. In general, the larger the plant capacity, the less the cost per unit of water. As has been mentioned previously, distillation is more economical for the desalting of sea water, while electrodialysis is better for brackish water. The water costs from nuclear fueled plants are approximately 10% less than from fossis fuel when used in large capacity (more than 100 mgd) plants.

The current cost of desalting is about one dollar per thousand gallons. This estimate is based upon an output capacity of 1 mgd, an amount representative of many plants currently in operation. Designs for the larger plants, such as for San Louis Obispo and Santa Barbara Counties, California, indicate costs in the vicinity of 73 cents per thousand gallons at the plant site. To this figure must be added delivery system costs.

G. Conclusion

Desalinization by numerous processes is already feasible in parts of the world when the natural water supply is either scarce or of poor quality. In these areas, the relatively high costs of water produced by desalinization are justified. Research[1] has indicated that when larger capacity plants are designed and in production, the costs for desalting sea water could ultimately be reduced to approximately 50¢ per thousand gallons, in the size range of the Northfield Mountain Project, although the proposed California plant would produce water at 73¢ per thousand gallons at the plant site. Even at this reduced cost, however, desalinization is not competitive with present costs of developing natural surface and sub-surface water supplies. For example, costs of water from this report's recommended project is about 15¢ per thousand gallons.

Aside from the economic costs involved with desalinization, the Office of Saline Water is also investigating the potential hazards to the environment which might occur. In considering placement for any type of desalting plant, environmental factors are as important as any other factor. Pure water is not the only product. A plant will produce extremely concentrated brine as an effluent, plus any waste products from the power source, such as soot, heat, smoke, toxic gasses, etc. So far as brine is concerned, this brine from distillation plants is of high temperature, higher chloride content and may contain concentrations of copper, all of which may prove injurious to the environment. Special design procedures would be required in the cases of estuaries or areas with restricted water interchange, as many life forms present might be adversely affected. Two land methods of disposal have been studied: (1) evaporation to dryness; and (2) deep-well injection. Evaporation is expensive, though this is highly dependent on land costs, presently quite costly in urban areas. Injection method costs are estimated at 25 to 70 cents per 1,000 gallons of brine. Such costs must be added to plant production and distribution costs to arrive at a true cost of water from this technology. At present, the Office of Saline Water is investigating other methods of brine disposal.

The future of desalting in the northeast is described as follows by the Office of Saline Water:[2]

"Existing desalting operations are characterized by several constraining features. Among the most important are high total annual costs, relative to conventional water sources; the need for proof of large-scale plant operation; and the problem of brine disposal. In the future,

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[1] Based on data contained in memorandum from Office of Saline Water to New England Regional Coordinator, U. S. Department of the Interior, 17 August 1972, based on 1972 price levels.

[2] Ibid.

as technology is further developed, several of the constraints will be lessened, and desalting may prove to be an attractive supplement to water supply in coastal and estuarine areas of the Northeast United States. Desalting processes may also serve future use as an aid in control of water quality." As a result, this report concludes that desalinization not be considered at this time as a viable alternative source of water in eastern Massachusetts for the short-range water supply problems. When and if the technology and efficiency of this process is refined so that it is economically and environmentally competitive with other methods of supplying water, its feasibility can be re-evaluated.

35. Importation

During the crisis years of the sixties' drought, many newspaper and periodical articles pondered the possibility of diverting water from extra-regional sources as a solution. One of the major basins often mentioned as a water supply source for the Northeast was the Saint Lawrence. As an alternative to developing local resources to meet future water needs, an investigation was made regarding the feasibility of diverting Saint Lawrence flow to meet future needs.

The Saint Lawrence River Basin is an impressive basin, both in its size and the annual runoff from its watershed. The drainage area is about 295,000 square miles at Ogdensburg, New York, which includes over 95,000 square miles of water surface area, most of which is in the five Great Lakes. Storage capacity within the lakes regulates the flow in the river to a large degree. The long term average discharge at Ogdensburg is about 240,000 cubic feet per second (155,000 mgd). From a review of these statistics, it is apparent that the basin, if developed, could meet the forecast supply demands for all of southeast New England.

Engineering studies were conducted to assess various methods and quantities of development from the basin. Cost estimates were prepared for projects which would service all of the Northeast through the year 2020. Construction costs for such facilities were estimated to be as high as 8.5 billion dollars, excluding any necessary water treatment costs. Water delivered from such an undertaking would cost substantially more than similar volumes made available from local resource potential.

In addition to the high cost of water, this alternative also has several other major disadvantages. First, the nature of the project would not allow stage development. Thus, large expenditures of funds would be required for distant long range needs. Second, since the basin is international, negotiations with Canada would have to be held and a treaty consummated prior to diversion. Assuming that Canada would be favorable to such negotiations, at best, any treaty would be in the distant future.

Based on the results of investigations conducted as part of this report, the importing of water to meet short-range water supply needs does not present a viable alternative for the southeastern New England Region's immediate problems.

36. Direct Waste Water Reuse as a Municipal Supply

Direct waste water reuse, especially in industrial process application, has been economically successful in many sections of the country. The Bethlehem Steel Company in Baltimore, Maryland, currently uses about 120 mgd of treated municipal waste from Baltimore and uses this effluent in its quenching and cooling processes. The Dow Chemical Company uses treated sewage from the City of Midland, Michigan for use in its cooling water and fire protection system. In Amarillo, Texas, effluent from the municipal sewage treatment is used as cooling water and boiler make-up water for industries located in that city.

Other uses to which treated waste water has been applied include irrigation of both crop land and lawns, as a fresh water barrier against salt water intrusion, and in some cases as a source of supply for formation of recreation lakes and ponds.

Direct reuse of waste water effluent as a public water supply, however, has not been utilized to a large degree. Advanced waste treatment research and development programs at the Federal level are continuing and pilot plant studies such as the noted Lake Tahoe project are apparently meeting with sucess in producing a high quality effluent.

The current Drinking Water Standards do not apply to direct reuse of reclaimed water for drinking. In a series of recent articles, the Division of Water Supply Programs, Environmental Protection Agency, (formerly Public Health Service) have described a number of potential health programs which could occur with the use of renovated waste water. As stated in these articles, recent public repercussions from birth defects caused by thalidomine and from the side effects of other new drugs, underscore the responsibility that health officials have in introducing or promoting the use of reclaimed waste water as a domestic source.

Health officials feel that many questions remain unanswered which must be fully investigated if renovated waste water is to be considered for drinking water purposes. Research considered vital was described in an article [1] prepared by the Director and Deputy Director, Division of Water Supply Programs. In their article, it was stated that "before development of intimate personal-contact uses of renovated waste waters, one needs to:

A. Initiate studies on viruses for:

1) Development of improved viral detection and enumeration methodology.

2) Exploration and definition of the basic properties of enteric viruses.

3) Provision of knowledge on transmission of viruses through the aquatic environment.

4) Definition of the impact of viral disease on man through associated epidemiological studies.

5) Development of technology for the positive removal and inactivation of viruses.

B. Investigate the potential problems from bacteria and other microorganisms in reclamation systems.

C. Identify and define the potential health effects of organic and other chemicals not removed by reclamation plants and subject to build-up, and develop techniques to identify and measure readily the concentrations of such chemicals.

D. Dispel the cloud that hangs over the whole subject of reliability for wastewater-treatment-plant operation. Reclamation plants for direct reuse must have fail-safe processes, back-up facilities, alternate means for disposal, continuous monitoring, and bioassay, and they must be operated in an atmosphere that demands reliability. State programs responsible for the operation of wastewater treatment plants

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[1] Lang, W. N. and Bell, F. A., "Health Factors and Reused Waters," Journal American Water Works Association, April 1972.

will require upgrading. Pilot and field-scale testing will be required for the validation of processes and practices prior to their widespread use.

E. Use common sense. Renovated wastewater should not be used for the ultimate personal use -- as a drinking-water supply -- until there is no other practical choice; and then, hopefully, the minimum research will have been completed and the use will be carefully operated and controlled. Meanwhile, in water-short areas, the renovation and reuse of wastewaters for industrial, limited irrigation, and other low human-contact purposes should be investigated and advanced.

The future of direct wastewater reuse, particularly in industrial applications, seems promising. Future water demand forecasts for industrial usage used in this report, in fact, anticipates greater recycling of water in the industrial sector. For example, industrial output projections of Standard Industrial Classification (SIC), category No. 28, Chemicals and Allied Products, indicate a 750% increase by 1990. Thus, if no recycling beyond that presently practiced were implemented, then anticipated water supply needs for this industry would increase over sevenfold. Future industrial supply estimates developed for this report, however, recognize many pressures are being exerted which should alter present industrial water use practices. In the SIC 28 category, described earlier, the possible changes in use practices were estimated to require a 370% increase in supply rather than the 750% which might be expected based on output forecasts.

Use of renovated waste water as a regular domestic supply, however, requires full results of proposed research. Until such research is completed, wastewater reuse as a municipal water supply is not a viable alternative to meet short-range supply needs.

37. Ground Water Resources

A study[1] of the ground water resources of Massachusetts was prepared for the Corps of Engineers by the United States Geological Survey. The study was based upon analysis and interpretation of available data and did not include any new exploratory work. The objectives of the study included an estimate of the area extent and sustained yield of principal aquifer reservoirs which might be used for supplementing municipal and industrial water supplies. The cost of producing the water was also estimated.

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[1] This investigation was conducted as part of the feasibility study of potential engineering alternatives in the study area.

A. Occurrence of Ground Water

A water bearing strata of rock material is called an aquifer. The principal aquifers underlying Massachusetts are of three types: 1) Stratified drift, layers of sand and gravel commonly interbedded with some silt and clay; 2) till, a non-stratified, poorly sorted mixture of clay, sand, gravel and boulders; 3) crystalline metamorphic and igneous bedrock. Till and bedrock aquifers yield small amounts of water, suitable only for domestic supplies. Only those aquifers occurring in stratified drift have the potential capacity to sustain large withdrawals of water.

Geologic reports and well logs were studied to determine the distribution and thickness of stratified drift deposits in Massachusetts. Deposits were found about everywhere in the state, but were most extensive in the valleys and outwash plains of the east and southeast area.

B. Hydrologic Parameters

In order to evaluate the aquifers as potential sources of water supply, their water transmitting and storage characteristics were studied. Permeability values, in gpd/sq. ft. were assigned to various lithologies such as gravel, sand and gravel and coarse - medium - fine sand on the basis of the relationship between grain size and permeability. The transmissibility, in gpd/ft., of a lithologic unit was then determined by multiplying the thickness of the unit by its permeability value. Coefficients of transmissibility and storage were also calculated from controlled pumping and drawdown tests at wells sunk in the aquifers.

The saturated thickness of the aquifers was mapped where data was available. The thickness was determined by subtracting the elevation of the base of the aquifer from the water table elevation. The saturated thickness of stratified drift, although not necessarily indicative of the presence of permeable zones, has been found by investigators to be a useable favorability guide for a general analysis of the ground water withdrawal potential. One further indicator of the water content of a ground water reservoir is the percentage of surface stream flow which is contributed by ground water. This portion of stream flow is termed base flow or ground water runoff. Analysis of past records indicates that average annual base flow of a given stream is approximately equal to Q-60 (stream flow equalled or exceeded 60% of the time) in a year of normal climate and equal to Q-70 in a dry year. The Q-70 flow is considered an index to the amount perennially available for consumptive use without depletion of storage.

The hydrologic criteria described above were applied to the principal aquifer reservoirs of Massachusetts. In this manner the capability of these reservoirs to serve as alternate sources of water supply could be evaluated. The rates of withdrawal from the aquifers were estimated by assuming the following conditions:

1) No recharge occurs for 200 days in dry years and all the water produced during this period is from ground water storage -- it is assumed that reservoirs capable of sustaining withdrawals under these conditions could continue producing forever;

2) The configurations of the reservoirs were idealized to form elongated rectangles;

3) A system of dewatering wells, 24" in diameter and spaced 2,000 feet apart for 2 mgd yields and 1,000 feet apart for 1 mgd yields, was hypothesized to aid in planning and cost estimates;

4) These wells were assumed to have no drawdown attributed to partial penetration, thinning of the reservoir, nor well losses;

5) Available drawdowns in the wells were limited to two thirds of the saturated thickness for water table conditions and to the top of the producing reservoir for artesian conditions;

6) Current withdrawals of ground water were included as a part of the estimated withdrawals.

The results were then tabulated by area and rate of withdrawal in mgd/sq. mile and total withdrawal in mgd.

C. Conclusions

The survey of ground water resources indicated that the aquifers in Plymouth County and parts of Cape Cod have the capacity to sustain long term, large magnitude withdrawals. The water demand on Cape Cod is increasing at a fast rate; therefore, this area is not considered in this report. The Plymouth County area studied comprises 300 square miles and its estimated safe yield is 300 mgd. This estimated rate exceeds the required quantity established as a goal at this study. Thus, it was concluded that the Plymouth County area could offer a viable alternative source of water supply for eastern Massachusetts.

Cost estimates for the necessary resource development were then prepared. Major development items included in these estimates were land acquisition, cost of ground water well development, water treatment facilities, pumping installations and connecting aqueduct system to the metropolitan service area. The estimated construction cost for the ground water development per million gallons per day (mgd) capacity is about 1.2 million dollars. Costs for the Millers River Basin - Alternative No. 2 on the other hand are estimated to be about $640,000 per mgd capacity. Annual costs of ground water development which include interest and amortization; maintenance, repair and operating cost; and major replacement costs are estimated to require charges of about 30¢ per 1,000 gallons produced. Annual costs for the Millers River Basin - Alternative No. 2 would require about 15¢ per 1,000 gallons produced.

In addition to the economic costs associated with development of the ground water alternative, there are also potentially significant environmental and socio-economic impacts. For example, land taking activities associated with sanitary protection of the various wells may be substantial. Preliminary estimates of necessary land acquisition for the wellfield development indicate 1,000 to 1,500 acres of land would be necessary. This compares quite unfavorably with the 40 acres estimated to be required for the Millers River Basin - Alternative No. 2.

Connecting pipelines between wells in the wellfield and transmission facilities to point of use would require a large amount of surface construction. Such extensive surface construction would have an impact on the environment in the vicinity of the wellfield and transmission facilities. Since portions of the aqueduct systems would pass through heavily urbanized areas, disruption would be expected to be extensive.

Since all water developed from the wellfield would have to be pumped to the consumer, this alternative would utilize large amounts of electricity. Thus, depending on the method used to provide this power, impacts on the environment may be expected. The Millers River Basin Project would utilize gravity feed; therefore, no additional potential environmental damage would accrue because of power requirements.

On the basis, then, of cost comparisons and potential socio-economic impacts, use of ground water does not appear to offer an attractive alternative to the proposed project.

38. <u>Dual Water Supply Systems</u>

An alternative which has been receiving attention of late has been the use of dual water supply systems. In these systems, a hierarchy of water supply would be established whereby higher quality supplies could be used to furnish a potable source for drinking, cooking, dishwashing, cleaning, bathing and laundering. All other uses could be furnished by a second supply of lesser quality.

Two general methods have been suggested for such a dual system. The first is the possibility of recycling at the point of usage. Under this scheme, drinking, washing and bathing water would undergo treatment and then be further utilized as toilet flush water and outdoor uses. It is estimated that such a system could reduce domestic water use by as much as 50%.

Various systems for in-house reuse or for outdoor usage have been proposed and some are being marketed on a small scale.

Advantages to this system beyond potable water consumption reduction is the reduction in sewage water volume, sewer pipe and pumping requirements. Capital cost outlay for such a system based on limited cost data would be over twice as expensive as water delivered from this report's recommended project. Other disadvantages to this alternative lie with its limited application and accompanying operational experience, potential problems of odor and other aesthetic considerations. Health officials, in general, have not expressed their acceptance or rejection of such systems. However, their general apprehension on introducing less than potable water into the home environment could also reasonably be expected with regard to any system of this nature.

The second method which has been suggested for delivering higher and lower quality water for various uses would require a second distribution system. This second distribution system would carry river water or even sea water to supplement the high quality primary supply source.

Two methods of providing the second (lower quality) distribution system could be employed. The first would involve installation of the entire system immediately. The second, and more practical, method would be on an incremental approach wherein secondary systems are installed in new or replacement buildings above a certain size. The second approach was evaluated in this report. With this approach, water consumption is only reduced at a given time by the building construction that utilizes secondary systems.

To estimate costs for such a system, a report on the New York City area prepared as part of the NEWS Study was utilized. Based on the results of that investigation, preliminary capital cost estimates for such a dual system would be about 6.5 million dollars per mgd saved. The Millers River Basin project recommended in this report is estimated to cost about $640,000 per mgd. Therefore, it is quite apparent that use of a dual supply distribution system as an alternative would be an extremely expensive alternative.

In summary, then, use of dual water supply systems does not offer an alternative to the recommended project in this report. Of the two methods, the system which would recycle water at the point of usage holds the more promise for future application.

39. Other Diversion Sites

In addition to the Millers River Basin - Alternative No. 2 proposal described in this report, a number of other diversion possibilities were also evaluated. These other possible sources included diversions from: the mainstem Connecticut River at other than the Northfield Mountain location; other tributaries of the Connecticut River; the mainstem of the Merrimack River and the Sudbury River, a tributary of the Merrimack, formerly used by the MDC.

A. Other Connecticut River Basin Alternatives

The possibility of diversions from the Connecticut River Basin mainstem appears to offer a viable companion source which when combined with the yield of the Millers River Basin Project would allow the system to meet its short and medium range needs. This project, named Northfield Mountain, is the subject of another Interim Report of Survey.

Alternative methods of diversions from the Connecticut River Basin, such as the Deerfield River or another location on the Connecticut River, could provide an equivalent yield to that of this report's recommended project. Development of either of these proposals, however, would be more expensive than either Millers River proposals or Northfield Mountain. Aside from economic costs, neither alternative appears to present any clear cut advantage from either an environmental or socio-economic standpoint. It appears then that development of these alternative sources would offer an opportunity for providing the necessary short-range water supply needs. Their development, however, would be more expensive and would not offer any advantage over the project recommended in this report.

B. Merrimack River Basin Alternatives

1) Merrimack River Mainstem

As an alternative to further diversions from the Connecticut River Basin, the potential of developing the Merrimack River mainstem was also investigated. Based on studies to date, use of the Merrimack River, to meet future needs, holds promise. Use of the river to meet immediate needs, however, does not appear to offer an alternative from either an economic or public health standpoint.

At present, the physical, chemical and bacteriological quality of the river is poor. For years the river has been subject to major discharges of municipal and industrial wastes. Because of these discharges, the Merrimack is often characterized as one of the ten most polluted rivers in the United States.

Even with the existing pollution load, the mainstem river is now used as a water supply for the Cities of Lowell and Lawrence. Water treatment facilities for both municipalities are conventional; however, taste and odor problems are experienced periodically at both locations.

Pollution abatement programs to implement secondary waste treatment facilities on point sources of pollution are under way by State and Federal agencies. Costs of these plants are estimated to be 235 million dollars. Upon completion of the abatement programs scheduled for 1976, the river will be improved as a water supply source.

A recent report by the Corps of Engineers,[1] in cooperation with the Environmental Protection Agency, investigated the feasibility of various alternatives for upgrading treatment processes beyond the planned implementation schedule. Cost estimates of the various alternatives ranged from 668 to 1108 million dollars. All of these plans would further enhance the quality of the river for use as a water supply source.

At present, the NEWS study is performing an Interim Report of Survey on those waste water treatment alternatives reported upon in the waste water feasibility report. The objective of this task is the evaluation of the various alternatives for their effectiveness in meeting the goals of the 1972 Water Quality Act. As a companion effort to the waste water element, investigations in survey detail on the river's potential for water supply development are also under way.

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[1] "The Merrimack: Designs for a Clean River," North Atlantic Division, Corps of Engineers, September 1971, Northeastern United States Water Supply Report.

In summary, at present, the Merrimack River Mainstem in Massachusetts is generally of poor quality. Alternative methods of treating the waste water discharges were assessed in a feasibility report by the NEWS Study. Followup survey detail investigations on alternative waste water treatment techniques and methods for developing water supply facilities are presently under way.

Based on studies to date, use of the Merrimack River to meet future water supply needs holds promise. Use of the River to meet immediate needs within the study area does not appear to offer an alternative to this report's recommended project from either an economic or public health standpoint.

2) Sudbury River

In 1846, the Cochituate Reservoir (previously Long Pond and presently Lake Cochituate) was acquired and developed to meet Boston's water needs through diversions from a subdivision of the Sudbury River watershed.

In 1872, the Sudbury River Act was passed which authorized the diversion of a portion of the Sudbury River waters to the Boston Water System. Subsequent to this Act, a series of reservoirs were construced by the Boston Water System and later by the Metropolitan Water District to develop the watershed. Construction on the last reservoir in the basin was completed in 1898 and a total of 75.2 square miles of drainage area was controlled.

In 1947, in response to the availability of supply from Quabbin Reservoir and the higher quality supply from this source, the Massachusetts Legislature transferred control of a number of the reservoirs to the Department of Conservation. The reservoirs transferred represented about 50 square miles of drainage area and were subsequently developed for recreational usage and their water supply use discontinued.

With its available supplies unable to meet its short range needs, the Metropolitan District Commission has reevaluated the potential which the full Sudbury system may have. Based on initial studies, it appears an additional 40 million gallons per day may be made available through flood skimming techniques.

The Sudbury Basin waters, however, have a number of water quality problems. Thus, to provide the potential yield, water treatment facilities would be necessary. Preliminary cost figures for needed facilities are estimated to be about 43 million dollars. In addition, transmission and pumping facilities may be necessary.

In order to fully estimate the potential and costs for redeveloping the Sudbury system, the MDC is preparing to initiate detailed investigations.

In summary, the "redevelopment" of the Sudbury River Basin could add an attractive increment to the available water supplies for this report's study area. Based on preliminary cost estimates, this increment is expected to cost about twice that of this report's recommended project. Yet to be determined as part of the MDC further study are the environmental and socio-economic advantages and shortcomings.

C. Conclusion

Alternative development of the Connecticut or Merrimack Rivers was evaluated as methods of meeting short range water supply needs forecast. Although either river basin offers opportunities, their development would be more expensive than the proposed project. In addition to economic considerations, use of the heavily polluted Merrimack River does not appear to offer an attractive alternative from a water quality standpoint for immediate supply needs.

The Sudbury system plan needs further study for a full assessment of its potential. If the Sudbury "redevelopment" plan were to be found attractive and constructed, it would be fully compatible with this report's recommended project and another element in the region's plan.

40. Water Demand Control

The NEWS Study, cognizant of the margin separating available yield and consumer demand, conducted studies on methods available to alleviate this critical water supply situation. Two general approaches to the problem were investigated: the first considered various methods of increasing the supply available to the system. The second approach described in this section was investigation of methods whereby demand could be curtailed.

A. Components of Demand

1) General

Water demand can be classified into four main categories. These are Domestic, Public, Commercial and Industrial. Nationally, of water withdrawn from public systems, 47 percent is delivered to domestic consumers; 13 percent to public uses; 18 percent to commercial; and

23 percent to industrial applications. A description of uses to which water is applied in the various categories is given in the following paragraphs.

2) Domestic

Domestic use, for purposes of this study, includes that water used by the consumer both within his home and that used by him for allied residential uses such as lawn sprinkling and car washing. In-house uses of water include drinking, bathing, cooking, washing and carrying away of wastes.

Total domestic water use in the United States amounts to approximately 73 gpcd. Few studies have been conducted regarding the composition of this demand; however, the U. S. G. S. reports domestic water in Akron, Ohio, was used in the following proportions:

TABLE 30

Domestic Water Use

Carrying Away of Wastes	41%
Bathing	37%
Cooking and Washing	9%
Drinking	5%
Clothes Washing	4%
Lawn Sprinkling	3%
Car Washing	1%
Total	100%

3) Public

Public or municipal use on a national basis accounts for about 28 gpcd of the average 157 gpcd supplied by public water utilities. Water used in this category is delivered to municipal facilities such as administration buildings, schools, hospitals, golf courses and other facilities used by the community at large. The water delivered in this category, of course, reacts to number and type of services provided. In Boston, for example, with a large number of hospitals and other institutions, it is reported that 38 percent of total water use falls within this category. In Wellesley, a suburb of Boston, only 9 percent is recorded as public.

4) Commercial

A significant portion of all water delivered from public supply systems is used by commercial establishments. Nationally, it is estimated about 28 gpcd are used for this purpose. Within this category, is included department stores, restaurants, hotels, laundries and other service elements which serve the general public. No breakdown of water delivered to the commercial sector was available for the Boston Metropolitan area, but it is estimated 850,000 commuters travel daily to the City of Boston. Water supplied to these commuters for their needs while "temporary residents" cannot help but be a significant share of the water supplied to the City.

5) Industrial

Many industrial establishments obtain their water supply from public utilities. Of the average 157 gpcd recorded in the United States, 36 gpcd were used in industrial plants. The water withdrawn by these industries is used for three principal reasons: cooling water; boiler water or water used for the generation of steam and process water, which is water that comes in contact with the product being manufactured.

Available records on industrial use which record individual community usage are limited. On a state-wide basis, about 100 mgd or 13 percent of the publicly supplied water was drawn for industrial use in 1968. Within the MDC service area, a recent telephone survey conducted by the NEWS Study indicated about 8 percent of water withdrawn was used for industrial. On this basis, then, Massachusetts and the MDC service area are not heavily industrial water users if compared to the national percentage of 23 percent.

B. Methods of Controlling Demand

There are basically five methods which have been suggested as effective in controlling demands on water supplies. These are:

a) Changing from flat-rate to metered supply
b) Increasing the price of metered supply
c) Imposing of restrictions on water use
d) Utilization of water saving devices
e) Public water conservation education programs

Each of these methods outlined above are described in the following sections as they might apply to the demand forecasts prepared for this report.

1) Metering

The installation of meters which measure the amount of water used by a consumer have been shown to be effective in varying degrees in reducing demand for water supply. With metering, the customer is now charged for the quantity of water used, instead of being charged a flat rate for a period of time regardless of quantity used. Most of the studies conducted regarding the effects of metering indicate domestic in-house use is relatively in-elastic, but lawn sprinkling use and some industrial applications apparently are affected.

Use of metering then appears to present a good opportunity for conservation of a resource. In the Boston area, however, application of this technique to reduce demand is quite limited. Most municipalities in eastern Massachusetts already meter extensively. For example, the MDC system is presently 96 percent metered. Complete metering, therefore, would affect only 4 percent of service connections in this system and not, therefore, affect to any significance water supply demands forecast in this study.

2) Pricing Effects on a Metered Supply

a) General

A number of articles have appeared in recent years in water supply and water resource professional journals regarding the impact of price increases on water demand. All of these articles attempt to quantify the constraining influence which pricing may have upon demands. In these articles, a number of various pricing techniques have been suggested for administration of price hikes. These include general increases in price levels, seasonal pricing and increasing block rates for varying usage of water. Aside from the administrative technique employed, however, the objective of the articles is to define impact of price increases on demand. Generally, the authors, however, are forced to base conclusions on a generally incomplete and sporadic empirical data base. In the following paragraphs, a brief description of some of the major empirical studies is given. Following the study descriptions, an application of the empirical data findings to the eastern Massachusetts forecast demand is made for both the domestic and industrial water components. Finally, an attempt is made to correlate the results of the empirically derived data to the local water supply system experiences. Although the data presented later is applicable to general pricing increases, the conclusions are felt to apply regardless of administrative technique selected.

In 1957, H. F. Seidel and E. R. Baumann[1] prepared a statistical analysis of various water works data. In their analysis, the authors derived an elasticity coefficient of 1.0 for certain price levels and a lower, inelastic coefficient for lower price levels. The authors, however, noted that they remained skeptical that a rate adjustment has the prompt, proportional effect on water use which the elasticity coefficients suggest. They stated their review revealed that most rate adjustments are moderate enough and water use habits sufficiently stable to consign the rate factor to a "distinctly minor role as an influence on fluctuations in water use."

Linaweaver, Geyer and Wolff,[2] during the years 1961 - 1966, conducted studies to determine patterns of residential water use and factors influencing this use. The results were then used to determine design criteria for water supply systems. These studies were sponsored by the Technical Studies Program of the Federal Housing Administration, and were in cooperation with sixteen water utilities in various climatic regions. Both residential and apartment areas were studied. Climate, economic level of consumers, and pricing systems were considered and concluded as having in that order the major influences on water use.

The economic level of the consumer was considered to influence water use for several reasons. A consumer in a higher valued area is likely to have more water using appliances which increase the overall domestic use. A second reason advanced is that a higher-priced house usually has a larger lawn which will increase the sprinkling demand. Climate is a major factor influencing sprinkling use when there is a lack of precipitation, but it has little effect on in-house use.

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[1] Seidel, Harris F. and Baumann, E. Robert, "A Statistical Analysis of Water Works Data for 1955," Journal of the American Water Works Association, XLIX, No. 12 (December 1957).

[2] Linaweaver, F. P., Jr., Geyer, John C., and Wolff, Jerome B., A Study of Residential Water Use, Washington: Department of Housing and Urban Development Report TS-12, February 1967.

The cost of water also influences the demand. Based on their findings, the authors conclude that cost does not influence in-house water use to a great extent, but would decrease sprinkling use.

Howe and Linaweaver,[1] using the results of the Residential Water Use Study,[2] studied the effect of water pricing in residential areas. Included in the results of this study was the formation of two equations which, according to the study, described the relation of price on use.

The domestic in-house demand was considered best expressed by the following linear equation:

$$g = 206 + 3.47v - 1.30p$$

where g = gallons per day per dwelling unit
v = market value of dwelling unit in thousands of dollars
p = price per 1000 gallons in cents

By use of this equation, the authors concluded that the effect of price on demand and the price elasticity of domestic use could be determined.

Based on their use of this equation, Howe and Linaweaver next concluded that domestic in-house use represented a demand relatively inelastic with respect to pricing changes.

Effect on summer sprinkling demands by pricing was considered as described by the following equation:

$$g = 3657\, r^{0.309} p^{-0.93}$$

where $r = b(w - 0.6s)$

and p = price per 1000 gallons in cents
b = irrigable area in acres surrounding dwelling unit
w = average summer potential evapotranspiration in inches calculated by the Thornthwaite method about 10" in the eastern United States
s = summer precipitation in inches

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[1] Howe, Charles W. and Linaweaver, F. P. Jr., "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," Water Resources Research, III, No. 1 (1967).

[2] Linaweaver, F. P. Jr., Geyer, John C., and Wolff, Jerome B. A Study of Residential Water Use, Washington: Department of Housing and Urban Development, Report TS-12, February 1967.

From use of this equation, it was determined that the sprinkling demand was responsive to price change. The Howe and Linaweaver work indicated, then, that residential water demand is dependent on the price charged. Typical in-house demands exhibited a price elasticity of -0.23,[1] e.g., a 10% increase in price will reduce demand by 2.3%, while the price elasticity for sprinkling demands was 0.93. Sprinkling use is, therefore, more strongly affected by price change than domestic use. The authors felt that pricing could be used as an effective tool to decrease average day demands and increase revenue.

Because of the different industrial water use requirements and variations in plant process flexibility, a single elasticity coefficient for all industrial use is probably unattainable. Research in this field appears quite limited. One small scale study, however, has been undertaken within Massachusetts and the results of this study are described in the following paragraph.

Coefficients of elasticity for water demand response to pricing changes were studied by Stephen J. Turnovsky.[2] This study was primarily directed to the question of the response of individuals to an uncertain supply of water. From data collected from a sample of Massachusetts towns, the coefficient of elasticity derived for household use was around 0.3, and for industrial demand, about 0.5.

c) Application of Prior Study Conclusions to Eastern Massachusetts

As described in the previous paragraphs, both Howe-Linaweaver and Turnovsky have developed equations and price elasticity based on empirical data which suggest the influence which pricing may have on demand. In an attempt to determine the significance of these relationships to current water demand in eastern Massachusetts, a computer program using these relationships was developed for communities serviced by the MDC.

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[1] based on a house market value of $20,000 and cost of water at 40¢/1000 gallons.

[2] Turnovsky, Stephen J., "The Demand for Water: Some Empirical Evidence on Consumers Response to a Commodity Uncertain in Supply," Water Resources Research, V, No. 2 (April 1969).

Once the computer program had been developed, a series of hypothetical price increases were imposed on the existing municipal rate structures. The effect of these increases on both domestic and in-house use and lawn sprinkling requirements are shown in the following table:

TABLE 31

Effect of Hypothetical Water Supply Rate Increases on MDC Demand,

Theoretical Decrease

Price Increase ¢/1000 gals	Domestic Demand	Lawn Sprinkling Demand	Industrial[1] Demand	Total
5	4.3	1.2	1.4	6.9
10	8.6	2.1	2.7	13.4
15	13.0	2.9	4.1	20.0
20	17.3	3.5	5.4	26.2
30	21.6	4.1	8.3	34.0
40	25.9	4.6	10.7	41.2
50	34.5	5.3	13.7	53.5

d) Discussion

As illustrated in Table 19, price adjustments would appear to offer an alternative to development of supplemental water supplies. Theoretically, a price increase of 50¢ per 1,000 gallons could be expected to reduce domestic or in-house demands by about 34 mgd and a corresponding decrease in lawn sprinkling demand by about 5 mgd. Industrial water use demands are indicated to react by decreasing almost 14 mgd. The total theoretical decrease on the system then with such a price increase would be about 53 mgd.

On the basis of the theoretical equations then pricing would appear to be a valuable tool for conservation of the water resource. A number of questions, however, arise concerning the direct application of these forecast decreased demands to the water supply situation at hand.

[1] does not include partially serviced communities

First, the empirical data used in the derivation of the domestic use equations, although the most extensive to date is far from all inclusive. Data used was derived from 21 areas nationwide, which contained about 5000 dwelling units. None of the test areas were located within Southeastern New England, although data available from the Middle Atlantic States was used.

In the analysis of industrial water demand reaction data utilized was quite limited, and other research in this area is almost non-existent. Development of any hard policy conclusions based on such sketchy information is, therefore, uncertain at best.

Second, the derivation of the empirical equations for domestic use was based on a "static" view of cost versus use. That is, the data employed was not an observation of a group of communities actual reaction to pricing changes. Rather the equations were developed by using a number of communities, which for a given point in time, had different water use with their individual rate structures. For example, Community A in 1970 used 100 gpcd at a cost of 20¢ per thousand gallons; Community B in the same year recorded an average use of 50 gpcd at a cost of 40¢ per thousand gallons. Based on the approach used by Howe and Linaweaver, the expected decrease in use from Community A with a price increase to 40¢/1000 gallons would be 50 gpcd. Whether the use of such a "static" scenerio to predict dynamic conditions is valid is unknown.

That the equations may not indeed reflect the dynamic situation which would occur with a price increase is particularly suspect with actual operating experience in the Boston Region. For example, in the Boston Region, the MDC increased wholesale prices for its water from \$40 to \$80 per million gallons in 1954, and \$80 to the current \$120 per million gallons in 1962. Neither of these price increases was accompanied by a decrease in per capita demand on the system, in fact, demand increased on the system.

To further evaluate the dynamic impact of pricing in an actual operating experience, a survey was made of a privately owned water company which recently applied a 24¢ per 1000 gallons to its water rates. This rate increase raised the cost of water to the consumer from \$1.00 to \$1.24 per 1000 gallons. The two communities serviced by the company are principally residential, thus the rate increase based on the empirical equation should be expected to result in a demand decrease or, in any event, a decrease in the rate of increase. The company reports, however, that instead of experiencing a decrease in per capita usage, it experienced a 5 gpcd increase, an increase in excess of that reported in years prior to the price increase.

Based on the actual operating experiences of these utilities within Metropolitan Boston, it appears that any arbitrary adoption of the empirical equation as a forecast tool with respect to water demand carries a large degree of uncertainty.

Third, all of the studies upon which the pricing - demand relationship was developed have been basically economic studies. No attempts have been made to evaluate or quantify cost to the consumers from either environmental quality or social considerations. Nothing systematic is known about such losses, in spite of the widespread occurrence of drought and shortage in recent years.

Both the social and environmental costs of reducing water demand may outweigh the gains derived from institution of such a policy. Whether, in fact, the costs would outweigh the benefits is unfortunately unknown.

In summary, use of increased water supply prices as a method to conserve a resource may have merit. Yet to be determined, however, are data to support the theoretical impact such increases would have upon the demand within New England. Also unknown with this approach are the social and enviromental costs which would be borne by the consumer. It appears then that much work remains to be done on this approach, such that it can be evaluated as a viable alternative to increased supply.

3) Imposing of Restrictions on Water Use

Historically, water utilities have used water use restrictions as a "safety factor" against depletion of supply during a drought. In general, however, most water utilities attempt to avoid restrictions whenever practical. Public reaction to such restrictions, however, is almost always unfavorable, and many examples of such public disapproval can be found in newspaper clippings during the recent sixties' drought.

Imposition of restrictions on water use could not fail to interrupt the existing and planned life styles of communities serviced by a water supply system. As described in the appendix on socio-economic impacts, restrictions on water use, depending on its degree, would have far reaching social and economic costs. On the basis of costs which would be incurred with a restriction policy, it does not appear to offer a viable alternative.

4) Utilization of Water Saving Devices In-House

Much of the recent increase in municipal water supply by individual consumers has been attributed to the adoption of multiple toilet facilities; water using devices such as automatic clothes and dish washers; and shower installations. Variation in water use between brand names differ markedly. For example, automatic home washers for an 8 pound load require from 32 to 59 gallons per load, while toilets vary from 3.2 to 8 gallons per usage. Information on the impact of domestic water saving appliances on in-house use is limited and variable in quality.

An article[1] presented last year in the American Water Works Association demonstrated possible water savings which could be brought about by adoption of presently available appliances for toilet, clothes washing and shower use. In this article, the authors sought to determine whether the residential consumer would financially benefit by adopting the most up-to-date water using appliances. Varying replacement strategies as a function of costs were assumed. Based on their findings, the authors conclude that there doesn't appear to be current financial incentives for adoption of water saving appliances. They do note, however, that conversely economic costs to consumers from utilizing water saving appliances do not seem great. Presumably, their conclusion refers to replacement costs when currently used appliances wear out. The authors suggest that complete replacement of appliances with water saving models might reduce domestic water use by 32 percent.

A second study[2] of water conservation measures for the Office of Water Resources, U. S. Department of the Interior, also contains some information on water saving devices. In this study, it was noted that

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[1] Howe, Charles W. and Vaugham, William J., "In-House Water Savings," Journal of the American Water Works Association, Vol. 64, No. 2, (February 1972).

[2] Hittman Associates, Inc., "Main C. Computerized Methodology for Evaluation of Municipal Water Conservation Research Programs," No. HIT-409, Columbia, Maryland, August 1969.

increasing use of water by automatic dish and clothes washers over the years has been occasioned by a rise in required performance standards. Thus, customer desires are reflected in the increased water use.

A third study [1] recently completed for the Washington Suburban Sanitary Commission provides a brief review on the effectiveness of water saving measures and the relationship of their use to rate-making policy formulation. In this report, the authors state, "A major deficiency in the data reported by all investigators to date is that it refers to isolated uses of specific appliances and fixtures, but does not reflect actual use conditions. For example, reducing the water requirement of a toilet from 5 to 3 gallons per flush may be assumed to produce a corresponding decrease in water demand for that particular use. If the modification required to accomplish this reduction, however, interferes with the flushing action of the toilet, then the result may be an increased number of flushes which partially or completely nullifies the expected savings."

In reference to the suggestion that 32 percent of the domestic water use could be saved by adoption of water saving devices, the authors state, "Such a result implies, of course, no reduction in the actual or perceived efficiency of operation of any of the appliances or futures. In the latter instance, the net reduction in water use is more difficult to predict; however, it should be somewhat less than 32 percent."

Statements made at a number of progress meetings suggested that use of incentives such as subsidies or tax concessions and revision of plumbing codes to require water saving devices would result in substantial water savings.

In general, however, the same questions which burden analysis of price as a demand moderation measure also apply to use of water saving devices. Regardless of managerial technique used to implement use of such devices (i.e., subsidy, tax concessions, etc.) the question still remains as to the effectiveness and impacts on water use which may occur. Research conducted to date has been limited and supporting evidence to prove or disprove possible water savings is lacking. In addition, socio-economic impacts which might occur with a general requirement that older appliances be replaced with the water saving

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[1] Boland, John J., Hanke, Steve H., and Church, Richard L., An Assessment of Rate-Making Policy Alternatives for the Washington Suburban Commission, Prepared for the Washington Suburban Sanitary Commission, September 1972.

models has not been addressed at all. Environmental impacts generated as a spinoff of producing the new replacement models may also be significant and must be included in any analysis.

In summary, adoption of water saving devices as a method of conserving water supply may have merit in the long run. At present, however, supporting data to measure the impacts of either requiring new housing units or replacement by older housing with water saving appliances is not available. Without this data, evaluation of potential savings as an alternative course of action to the recommended project cannot be documented.

5) Public Water Conservation Education Programs

Historically, the water supply industry has not advocated wide scale public water conservation, except in communities where supply or distribution systems were inadequate to meet demand. Recently, however, increased awareness of the need to protect and enhance the environment has required a review of this earlier policy.

At present, two[1] major metropolitan supply systems have adopted a water conservation policy during a time of water surplus. In the past year both utilities have promoted expanded voluntary customer water conservation through a public education program.

Bill inserts and information handbooks on water saving measures have been distributed widely. In addition, speeches to individuals, schools and clubs have been employed to inform the public of why the water resource should be used properly and what they can do to help conserve water. Results of the education programs are now being evaluated for their effectiveness.

The Washington utility which has the longest experience record reports results have been encouraging to date; however, major reductions in per capita usage have not been observed.

In addition to voluntary conservation measures, the two utilities are also considering the use of regulatory powers to conserve water. Regulatory measures under consideration include, for example, price increases, utilization of water saving household appliances and

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[1] Washington Suburban Sanitary Commission and East Bay Municipal Utility District. Note: both utilities service populations of about 1.1 million each.

restriction of lawn sizes. All such measures, however, are being carefully evaluated by the utilities because of the many questions, described in earlier sections, which surround use of such devices.

In summary, adoption of public water conservation programs as a management tool has received attention of late. Results on water use modification of the voluntary conservation programs now under way are limited. However, based on the Washington area experience, no major decrease in per capita usage has been observed.

41. Re-examination of the Swift and Ware Rivers Downstream Release Schedules

At the time diversions were contemplated from the Connecticut River Basin, via the Swift and Ware Rivers, Massachusetts applied to the Secretary of War for authority to make the proposed diversions. After hearing arguments pro and con from Massachusetts and Connecticut, the Secretary permitted diversion of the flood waters of the Ware in excess of 85 million gallons per day between 15 October and 15 June and prohibited the taking of any water except during that period.

With regard to the Swift River, the Secretary permitted diversion of all waters of the Swift except enough to maintain a flow therein of 20 million gallons per day (mgd) or 31 cubic feet per second (cfs). The Secretary did require that during the period from 1 June to 30 November there shall be released from the impounding dam 71 mgd (110 cfs) whenever the flow of the Connecticut River at Sunderland, Massachusetts is 4650 cfs and 45 mgd (70 cfs), when the flow is more than 4650 and less than 4900 cfs.

These findings of the Secretary of War regarding operational schedules for the diversions were later made a part of the Supreme Court Decision, dated March 1931, in the suit between Connecticut and Massachusetts. Since the date of that decision, diversions from the Swift and Ware Rivers have been accomplished under the Secretary of War findings.

During the progress of the NEWS Study, an interested citizens' group suggested the setting aside of the Swift River diversion limitations with the objective of retaining presently scheduled releases within Quabbin Reservoir. The citizen group further suggested any diminution of flow in the Connecticut River could be made up by releases from existing

Corps of Engineers' flood control reservoirs. In keeping with this suggestion, an examination was made of the potential which such re-scheduling might have on the short-range supply problems.

The drainage area of the Swift River controlled by the Quabbin Reservoir totals 186 square miles. The long-term average annual runoff from the watershed is 187 mgd (289 cfs) of which 32 mgd (50 cfs) has been released downstream in compliance with the existing downstream release schedule.

Thus, the maximum addition to the existing water supply system which could be achieved through re-scheduling would be 32 mgd (50 cfs). To provide this increment, however, all downstream releases would have to be terminated. Such a complete cessation of downstream releases with the subsequent "drying up" of the river reach downstream is, of course, impracticable. The question then raised is what level is practicable. A recent study[1] completed for the entire Connecticut River Basin recommends an instantaneous discharge rate, from power reservoirs on the Connecticut River of 0.20 cubic feet per second per square mile of upstream watershed. An application of this criteria to Quabbin Reservoir, for example, would result in a downstream release requirement of 24 mgd (37 cfs). Adoption, then, of such a modified operational schedule could result in an additional 8 mgd being made available. This increment of yield, however, would not begin to meet the short-range needs of this report's study area which are estimated to total an additional 141 mgd. In short, then, a re-examination of downstream release schedules with the objective of conserving such releases for water supply has merit. However, based on the requirement of maintaining a viable river environment downstream from Quabbin, the opportunity for reducing downstream releases does not offer an alternative.

The spring runoff which occurred in 1972 was of longer duration and of greater magnitude than is usually experienced. As a result, diversions from the Ware River, in compliance with the operation schedule described earlier, were forced to cease even though flows in excess of 85 mgd were still occurring. This event triggered a suggestion to the NEWS Study that if the 15 June to 15 October no diversion constraint were lifted, large additional supplies of water could be made available to Quabbin.

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[1] Comprehensive Water and Related Land Resources Investigation, Connecticut River Basin, Connecticut River Basin Coordinating Committee, June 1970.

A computer test was made to determine the impact of the 15 June to 15 October constraint. The results of the computer simulation indicated that only an additional 2.6 mgd might be made available if the 4 month no diversion period currently in effect was terminated.

In the Ware River, as in the case of the Swift River, a re-examination of downstream release schedules may have merit. However, terminating the 15 June to 15 October diversion period constraint does not offer an alternative to this report's recommended project.

SECTION XII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This report has investigated and assessed all aspects of the water supply situation within the study area. The Metropolitan District Commission (MDC), Boston, is the largest regional system in New England, supplying about two million people in 1970. The MDC relies upon surface water as its supply source, and the present estimated safe yield of these sources is 300 million gallons per day (mgd). In 1971, the average daily delivery of water from this system was about 322 mgd. Thus, at present, available safe yield of the largest regional system in New England has been outstripped by rising supply demands.

The land area encompassed by this study falls within the boundaries of the so-called "megalopolis" which extends from Boston, Massachusetts to Washington, D. C. Latest population estimates for the Massachusetts study area forecast increases from 5.5 million in 1970 to 6.7 million by 1990, and 8.4 million by the year 2020.

Estimates of future water requirements within the region and on the existing regional system demonstrate the need for additional supply. Development of a single regional system to meet 1990 needs of all communities within the study area was not found to be an attractive approach, either from an economic or resource utilization viewpoint.

Based on a review of the area's 1990 water supply needs, it is concluded, the MDC system, as it exists at present, will require additional supply. In addition, studies reveal about 24 communities which may require admission to the system to satisfy their short range (1990) needs.

The estimated total demand for 1990 for presently serviced and other needy communities on the existing regional (MDC) supply sources is calculated to be about 441 mgd. Future demand forecasts were derived using both population and industrial output projections. In general, although some modification of consumer and industrial water usage patterns are included in these estimates, no major modifications or shifts in usage patterns are included.

In order to meet the 141 mgd additional demand, a large number of alternatives were investigated to determine their environmental and socio-economic impacts. Alternatives to the Millers River Basin project included no action, desalination, groundwater development, waste water reuse, other diversion sites, re-regulation of existing supply sources, local resource development and controlling the water supply demand. Based on the investigations conducted, it is concluded that the Millers River Basin supply project offers an attractive opportunity for providing early relief to the short range needs.

In the evaluation of the Millers River Basin Project, particular attention was given to the impacts on downstream water users which implementation might cause. All of the investigations indicated minimal downstream effects could be expected with operation of the project.

On the other hand, implementation of the project would provide protection against water shortages and associated socio-economic losses. Estimates of economic losses prevented when compared to project costs demonstrate the economic efficiency of the project. With respect to the Regional Development objective, the project would provide a benefit/cost ratio of 1.2 under average runoff conditions; and under a hypothetical drought situation, the ratio was estimated to be 1.8. In the National Economic Development account, the benefit/cost is estimated to be 1.1 under normal and 1.6 under drought runoff conditions.

In assessing the Environmental Quality Impact, the Connecticut River Estuary, the river itself and the receiving water body at Quabbin Reservoir were examined to determine what changes would accompany the project's implementation. In general, minimal changes can be expected in the river and estuary downstream of the diversion intake. These minimal impacts forecast are due to the relatively small diversion volumes compared with river flow. Within Quabbin Reservoir, the diverted flow may have impacts depending to a large degree on the pollution abatement steps taken. For example, the present waste loads may provide opportunities for localized algae growth or oxygen depletion. The Metropolitan District Commission is currently investigating certain chemical and physical parameters to better define the probable impacts on the reservoir.

Based on all investigations conducted, it is concluded that resources are available within the region which can be developed from both economical and environmental viewpoints. Development of these resources through the Millers River Basin Project and a companion project (subject of another report) offers a means of meeting supply needs through 1990. The availability of the resources and the opportunity for their development provides an optimistic outlook for the region at least in the short run.

In addition to the conclusion that the Millers River Basin Project should be implemented, it is also felt that concurrent investigations on water demand and its makeup should be conducted.

For example, detailed breakdown of water use or demand by consumers is not readily available. Although use, on a per capita basis, is readily available, data on how and by whom the water is used is not well documented. Increased per capita demands are, of course, a reflection of the nation's rising standard of living, but the breakdown of this demand into various use categories is poorly understood. A clearer understanding of the breakdown would permit the most efficient long range use of water supply resources.

Household items, which are undoubtedly contributing to increased water usage, include clothes and dish washing machines; multiple toilet facilities, and installation of shower facilities. Among these appliances, a wide range of water requirements per usage is needed. A search of available literature indicates these wide variances in water requirements may not be occasioned by economic or environmental efficiency objectives, but rather the result of independent design criteria. It appears then a rationalization of criteria used in design of water using appliances may offer opportunities for reduction of longer range water needs upon the public supply systems. The true measure of this opportunity would require extensive investigation, including the various appliances' efficient water needs; the impact which re-design would have on consumers; identification of incentives necessary to achieve full use of such devices, such as use of plumbing regulations, subsidies, and the effect which such potential in-house savings may have on future, particularly long range, water demands.

A second area worthy of investigation regards the impact which restructuring of pricing policy as a conservation measure for long range needs may have. Studies conducted to date indicate increases in cost of water supplied to the consumer may decrease use of water by the individual. Data developed to date on this pricing/use reaction has been limited. Thus, any theoretical anticipated decrease in water use caused by a price hike must be viewed as speculative.

In addition, none of the work has addressed the question of whether such price increases would in fact be beneficial or detrimental to the socio-economic objectives of the public water supply consumer. For example, if water rates were raised substantially in excess of the economic costs of delivering the water, the rate increase would in effect be a tax placed upon the consumer; consequently, questions of equity then arise. In short, the use of pricing as a conservation tool is an unproven venture, given the present "state of the art" concerning its potential benefits and possible shortcomings.

During the course of the study, at a number of informal progress and formal public meetings, it became evident that the general public was apathetic with regard to its water supply systems. At three public meetings held in the Boston metropolitan region, the area which could be supplied water from this report's recommended project, less than 50 people attended each of the meetings. It appears that the public takes its present good quality and available water as unlimited. This attitude can be attributed, in part at least, to the continuing availability of supply made available by the efforts of the local and regional water supply agencies. The question arises, however, whether such casual public concern over their water resources is a healthy state of mind. Many conservation groups at the NEWS meetings characterized this lack of public concern as leading to misuse of the resources through waste. There is no evidence to substantiate this charge in the study region. However, an education program to inform the public about their supply system, its limits and future, is in consonance with good management practice. The development of such an educational program, therefore, not only within the study area of this report, but nation-wide, should be considered as part of any water supply plan.

Throughout the conduct of this study, a number of groups, primarily conservation oriented, have advocated the re-cycling of waste water for water supply uses. In some cases, such as in certain industrial processes, effluent from waste treatment facilities can be utilized. The use of such waste water effluent, regardless of the degree of waste water treatment, as a source of supply for municipal systems is not sanctioned at this time. Echoing the position of the Division of Water Supply, Environmental Protection Agency, State and local health officials and professional water supply engineers, any application of reused water as a municipal supply would require a considerable amount of research on associated potential health hazards. Since, in many regions, less than desirable sources may be needed in the future, it is imperative such research be accelerated.

As part of the legislation establishing the NEWS Study, the Secretary of the Army, acting through the Chief of Engineers, was authorized to prepare a plan to meet the long-range water needs of the Northeastern United States. Such plans were to be prepared in cooperation with Federal, State and local agencies and were "to provide for appropriate finanial participation from States, political sub-divisions and other local interests." In keeping with these study objectives, the NEWS Study has conducted investigations on institutional and financial options for implementation of the various projects. These investigations were conducted by public administration consultants [1] as well as by in-house NEWS personnel.

Five major institutional options that encompass a full range of alternatives for centralization/decentralization of control and financing within the northeast, including Southeastern New England, were investigated. The five options are:

> Local Initiative/Federal Planning -- A continuation of present institutional arrangements and trends
>
> Strengthened Systems of Local Initiative -- Regional water supply councils established on the base of major metropolitan systems
>
> State/Federal Leadership -- Federal planning and state construction and management of major new water supply sources (wholesale only)
>
> Federal Initiative -- Federal planning, construction and management of new water supply sources (wholesale only)

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[1] "Organizational, Legal, and Public Finance Aspects of Water Supply for Southeastern New England and the Metropolitan Area of New York City - Northern New Jersey - Western Connecticut," prepared by the Institute of Public Administration, New York, New York, July 1972, for the North Atlantic Division, Corps of Engineers.

"Legal, Institutional and Cost Sharing Requirements for Implementing Water Supply Projects in the Northern New Jersey - New York City - Western Connecticut Metropolitan Area," prepared by Booz-Allen Public Administration Services, Inc., June 1973, for the North Atlantic Division, Corps of Engineers.

"Water Supply Cost-Sharing Alternatives," prepared by Linton, Mields and Coston, unpublished, for the North Atlantic Division, Corps of Engineers.

"Institutional Analysis, Southeastern New England," prepared by Linton, Mields and Coston, unpublished, for the New England Division, Corps of Engineers.

Intergovernmental Water Resources Corporation -- Corporation established by the three states to manage wholesale water supply development and operation for the entire area.

The options range from decentralized control and financing (as represented by the Local Initiative/Federal Planning Option) to a highly centralized option represented by the Intergovernmental Water Resources Corporation.

On the basis of all investigations, it was concluded that existing State institutions can operate the Millers River Basin Project and the overall regional system which would be augmented by implementation of the project.

As described earlier, the legislation which spawned the NEWS Study instructed the Corps of Engineers that any plans "shall provide for appropriate financial participation by the States, political sub-divisions thereof, and other local interests." In response to this directive, the NEWS Study also conducted a number of investigations [1] on financial options for implementation of the various projects.

As described in the cited references, the provision of water supply in the northeastern part of the United States has historically been a local (non-federal) function. In each of the states investigated, numerous water supply utilities, both public and privately owned, furnish water to small communities, large cities and metropolitan regions. The methods of financing these utilities are many and varied; however, a general rule which fits all is that local benefiting jurisdictions share among themselves the major costs of water supply development and operating costs.

Present Federal cost-sharing policies for water resources development have been developed by the Congress and by administrative decisions. The Congress establishes general policy in two ways. The first is through formal statements of cost-sharing policy contained in legislative acts covering broad programs such as flood control and water quality control. The second way is by Congress repeatedly authorizing Federal agencies to carry out specific programs or activities, and including cost sharing arrangements in the authorizations. When this is done consistently over a period of time, it is usually considered that a firm congressional policy has thus been established.

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[1] op cit., page

The legislation establishing the Northeastern United States Water Supply Study (NEWS) falls into the latter method of policy making described above. In addition, the Millers River Basin Water Supply Project is one of the first authorization documents to be submitted under the NEWS legislation; therefore, any action taken on this project cannot be considered as an adoption of a general policy.

Federal interest in water supply, evident for more than half a century, began with a focus on the water short areas of the American West. Since the mid-1950's, water supply and related water problems in the Northeast have received increasing attention in Congressional hearings, bills, and speeches, and reports from the President's Executive Office.

Generally, the rationale for the involvement of Federal cost sharing in water supply development and distribution has been based upon two arguments:

1) The inability of the local utilities to secure adequate or reasonable credit

2) Increased public demand for water facilities

In 1955, the Housing Amendments Act, Title II, established a program for public facility loans to assist states and municipalities (esp. with populations under 10,000) to provide water, sewage and other facilities.

In 1958, the Water Supply Act provided authority for the Corps and the Bureau of Reclamation to include storage for immediate and future water supply uses in federal navigation, flood control, irrigation or multi-purpose water supply projects.

In 1961, Amendments to the Water Supply Act of 1958 authorized 30 percent Federal grants to assist in meeting costs of establishing and maintaining adequate measures for prevention of water pollution. This legislation also contained authority for Federal agencies (Corps and Reclamation) to include capacity in reservoirs to be used for anticipated future water supply demands. Prior to this point (1958 Act), contracts had to be entered into for that portion of the supply allocated to future demands and reasonable assurances obtained for repayment. This was changed in 1961 to resolve the problem which occurred where projects could provide capacity for future municipal and industrial demands, but no entity yet existed to contract for such future use.

In 1965, four significant pieces of water legislation were passed:

The Rivers and Harbors Act of 1965 (89-298) authorizing the NEWS Study to plan a system of reservoirs, aqueducts between major basins, and treatment facilities.

The Water Resources Planning Act which called for multi-purpose river basin plans. (The NEWS Study, for example, would incorporate river basin plans into its regional plan).

The Housing and Urban Development Act of 1965, which provided Federal matching grants of 50 percent for water and sewer and treatment facilities. This legislation was aimed primarily at encouraging orderly development and serving immediate growth needs. Note, the conference report amended out the use of these funds for treatment facilities.

The Rural Water Facilities Act cited lack of available credit to finance new rural water systems and was justified partially as a result of the Housing and Urban Development Act which was serving primarily urban communities.

In summary, the provision of water supply in the northeastern part of the United States has historically been a non-Federal function. Federal interest in the nation's water supplies began with a focus on water short areas in the west. Since the mid-1950's, however, national interest in the form of several legislative acts has also included the large urban population in the northeast. Federal cost sharing in water supply activities includes many forms such as 50% grants for certain facility development as well as long term loans for construction of water supply storage. In all cases, operation and maintenance costs are borne by non-Federal interests.

Financial options investigated as part of this study included options such as modifications to the Water Supply Act of 1958 as well as the possible use of grants. Each of these methods have their own advantages and disadvantages with regard to meeting the requirements of the NEWS Act. However, on the basis of all investigations conducted, it is concluded that the general provisions of the Water Supply Act of 1958 excluding treatment facilities should be utilized in financing the Millers River Basin Project.

In summary, then, the Millers River Basin Water Supply Project would be an important supply increment in the regional plan for the metropolitan Boston area and appears compatible with the short and long range water resource development objectives of the region. Included in the regional plan for the Boston area would be the Northfield Mountain Project described in a companion report. Also, there is the possibility of utilizing the South Sudbury River and/or the Merrimack River for future demands. Studies may find that certain measures designed to conserve and moderate water demand should be implemented to reduce the size of needed long range water supply developments. For the region as a whole, water resources are available which can be developed efficiently from both an environmental and economic viewpoint to meet the water demands. Sources include the Merrimack, Taunton, North and Connecticut River Basins, together with local groundwater sources. The future view of the area, therefore, can be described as optimistic. However, a continuing planning program, dynamic in nature, must be pursued to insure adequate, safe, dependable water supplies are available when necessary.

Recommendations

The water supply needs of the metropolitan Boston area are both of an immediate critical and regional nature, such that it is within the national interest for the Federal government to participate in assuring the adequacy of the region's water supply system. The Millers River Basin Water Supply Project would be an important supply increment in the regional plan for the metropolitan Boston area and appears compatible with the short and long range water resource development objectives of the region.

Accordingly, the Division Engineer, New England Division, recommends that the Federal government participate in the design and construction of the water supply components of the Millers River Basin Water Supply Project. Necessary treatment facilities for the project, however, would be designed and constructed by non-Federal interests.

Consideration was given to the institutional arrangements necessary to operate this project and the expanded regional water supply system. From these investigations, the Division Engineer concludes that existing State institutions can operate this project and the overall regional system in light of objectives set forth in Title I of Public Law 89-298.

Investigations on cost sharing options by the Federal Government in regional water supply projects were also conducted in accord with directives set forth in Public Law 89-298, Title I. These studies indicate that a larger Federal participation than presently authorized in funding of water supply projects may be warranted. Thus, in order to assure adequate water supply for the eastern Massachusetts Metropolitan Center, the Division Engineer believes that the provisions of the Water Supply Act of 1958, with certain modifications, should be used. The modification which is necessary to make the 1958 Act responsive to the current supply needs is a deletion of the stipulation that only costs of storage in flood control reservoirs apply under the law. This modification, however, would not apply to any treatment facilities which may be needed. Such treatment facilities are considered a non-Federal interest cost.

The Division Engineer also recommends that studies be conducted by the Federal Government to define the potential impacts which measures designed to conserve and moderate water demand may have on long range supply needs. These studies would include an assessment of the impacts which such measures may have on the consumer as well as on needed future supplies. Such investigations would be designed to provide data applicable nationally.

The Division Engineer supports the position of the Environmental Protection Agency that "water quality standards be adopted as soon as practicable for intrastate waters which are presently unclassified, and approved standards on interstate waters be met."

The Division Engineer further recommends that water quality in the Millers River Basin and in Quabbin Reservoir be monitored by responsible Federal and State authorities to insure the safety and purity of the water.

He further recommends that the project be authorized subject to the condition that local interests, prior to construction, furnish assurances satisfactory to the Secretary of the Army that they will:

A. Institute with the State of Connecticut agreements pursuant to the diversions contemplated in the recommended project.

B. Reimburse to the United States the entire amount of the construction cost including interest during construction. Such reimbursement shall be repaid within the life of the project, but in no event to exceed 50 years after the project is first used for water supply purposes, except that no payment need be made with respect to facilities designed for future water supply until such supply is first used; and (2) no interest shall be charged on such cost until such supply is first used, but in no case shall the interest free period exceed ten years. Limits on the cost of a project which may be allocated to future water use and the interest rate used for purposes of computing interest during construction and interest on the unpaid balance shall be determined as specified in the Water Supply Act of 1958.

C. Hold and save the United States free from damages due to the construction works, or changes to water rights.

D. Continue to operate and maintain existing public use, access, and landing facilities for recreational boats at Quabbin Reservoir, open to all on equal terms.

E. Provide public access to those areas which may have recreation development potential occasioned by construction activity in accord with local health regulations.

F. Agree to cost share under provisions of P. L. 89-72, should suitable opportunities for recreation development materialize during the post authorization phase.

G. Operate and maintain all features of the project after its completion in accordance with regulations prescribed by the Secretary of the Army including allowances for major replacements.

H. Investigate and institute those measures found practicable to enhance the conservation and wise use of the water resources used for supply.

I. Provide a mechanism through which communities can be reimbursed for taxes lost through acquisition of land necessary for this project.

J. Initiate a continuing Public Education Program designed to inform the public on the need for wise use and conservation of their water supply resource.

K. Insure that communities within the Commonwealth which require additional short range supply are eligible for admittance to the water supply system.

JOHN H. MASON
Colonel, Corps of Engineers
Division Engineer

NADDE (25 Oct 1974) 1st Ind
SUBJECT: Millers River Water Supply Project Survey Report

DA, North Atlantic Division, Corps of Engineers, 90 Church Street, New York, New York 10007 5 November 1974

TO: HQDA (DAEN-BR/Resident Member) Kingman Bldg., Ft. Belvoir, Va. 22060

I concur in the conclusions and recommendations of the New England Division Engineer which support the authorization of Alternative No. 2, the Tully-Millers River Diversion.

James L. Kelly
JAMES L. KELLY
Brigadier General, USA
Division Engineer